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Stratigraphic Distribution of Brachiopods and Bivalves in the Upper Devonian (Famennian) Chagrin Shale in the Cuyahoga River Valley, Northeast Ohio

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Abstract

The Upper Devonian Chagrin Shale, exposed in the Cuyahoga River Valley in northeast Ohio, has a relatively rich, brachiopod-dominated fauna. Two stratigraphic sections were sampled to determine the distribution of brachiopods in these shale and siltstone beds. Nineteen brachiopod and four bivalve taxa have been described from the unit in this study. Conodont faunas, and to a lesser extent, brachiopod ranges, provide evidence of a late Famennian age for the Chagrin Shale

The Chagrin sediments were deposited on a relatively shallow shelf, below normal wave base. Sedimentation rates were slow, energy was low, and the substrate was fluid. Turbidity was at least moderate, as evidenced by dominant colonization by brachiopods instead of bivalves. Episodic storms carried sediments westward from the prograding Catskill Delta complex, leading to the periodic burial of brachiopod communities. The low degree of fragmentation and lack of abrasion of specimens suggest rapid burial rates. Preservation was influenced by the processes of dissolution, pyritization, and phosphatization.

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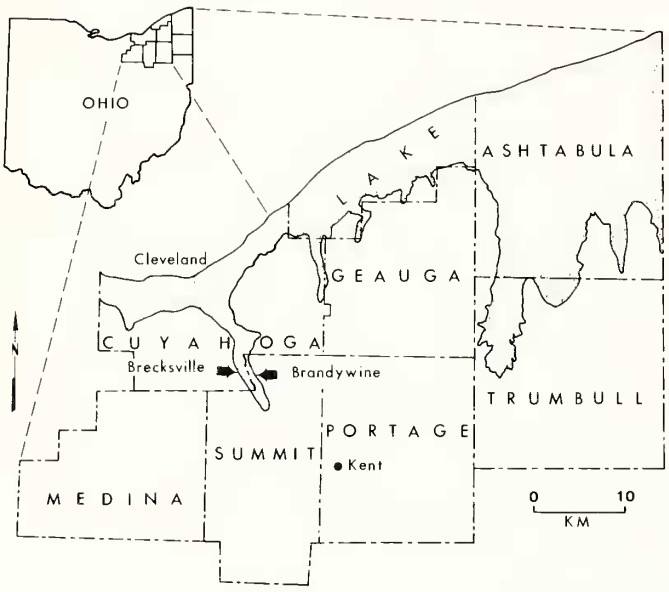


FIGURE 1. *Upper Devonian shale outcrop pattern in northeastern Ohio, showing the locations of the two study sites in the Cuyahoga River Valley.*

Introduction

The purpose of this study is to describe brachiopod and bivalve faunas and their stratigraphic distribution in the Chagrin Shale from Chippewa Creek at Brecksville Reservation on the western side of the Cuyahoga River Valley, and from Brandywine Creek at Brandywine Falls, on the eastern bank (Figure 1). The brachiopod fauna supports a late Famennian age for the Chagrin Shale.

The Chagrin Shale is exposed across 150 kilometers of northeast Ohio, along the southern shore of Lake Erie, and along many of the streams and their tributaries which flow into the lake (Figure 1). The Chagrin attains a maximum thickness of 400 m at the Ohio-Pennsylvania border, and thins to an estimated 35 meters in the Cleveland area according to Szmuc et al. (1976). Pepper et al. (1954) described the Chagrin as a thick wedge of interbedded siltstones and shales, bounded above by the Cleveland Shale, and below by the Huron Shale, and pinching out between these two black shales in a westward direction. The Cuyahoga River flows through the western part of the Upper Devonian shale outcrop area, where its valley is floored by the Chagrin Shale. From Cuyahoga Falls, Summit County, the river travels northwest across Summit and Cuyahoga Counties in a pre-glacial valley, characterized by steep hills and cliffs for many miles. The Cuyahoga River tributaries often cut valleys or gorges through the hills, in which many of the best Chagrin Shale exposures are seen.

Various aspects of the Chagrin Shale have been studied in recent years: the petrography (Broadhead and Potter, 1980); facies relationships (Potter et al., 1980); sedimentation (Potter et al., 1980); trace fossils (Feldmann et al., 1978; Hannibal and Feldmann, 1983; Stukel, 1987); and arthropods (Weidner and Feldmann, 1983). Previous reports (Prosser, 1912; Cushing et al., 1931; Hannibal and Feldmann, 1983; and Weidner and Feldmann, 1983) cited the sparsely fossiliferous nature of the Chagrin Shale. While faunal elements are restricted, recent studies, listed below, concluded that the Chagrin fauna is more diverse and abundant than previously supposed. Stukel (1987) described fifteen ichnotaxa from the unit; Weidner and Feldmann (1983) reported several species of arthropods found in the Chagrin; and Feldmann et al. (1986) identified fossil worms from the unit. The most abundant megafaunal elements appear to be brachiopods, with bivalves as a minor constituent of the total fauna.

Localities

Locations of the two sections studied are shown in Figure 1. Chippewa Creek, located on the western side of the Cuyahoga River Valley, flows through Brecksville Reservation, one of the Cleveland Metroparks. The Brecksville section is located in the west-central 1/9 of the Northfield, Ohio 7.5 min. topographic map (1963, photorevised 1979). The section begins on the southern side of the creek, at the base of the Bridle Path, and extends upstream, approximately 900 m, to a steep cliff on the north side of the creek. The upper part of the measured section is approximately 170 m north of the Trailside Interpretive Center on Chippewa Creek Road.

Brandywine Creek, part of the Cuyahoga Valley National Recreation Area, lies on the eastern side of the Cuyahoga River Valley. It is located in the southeast 1/9 of the Northfield, Ohio 7.5 min. topographic map (1963, photorevised 1979). From the intersection of Brandywine Road and I-271 on the map, the measured section is 580 m west on Stanford Road, and 50 m north into the park area. The Chagrin crops out on the banks of Brandywine Creek for almost a kilometer, ending west of a waterfall, approximately one-half km upstream.

Lithologies

The Chagrin Shale consists of interbedded greenish-gray to bluish-gray shales, and discontinuous siltstones. The siltstones range in thickness from one to tens of centimeters, generally increasing in number and thickness eastward, toward the Ohio-Pennsylvania border (Stukel, 1987).

At Brecksville Reservation, the Chagrin Shale exposure measures approximately 6 m from stream level, at the base of the Bridle Path, to the contact with the overlying Cleveland Shale. Here the Chagrin consists of

generally fissile, greenish-gray shales, current-rippled, cross-laminated siltstones, and plane-parallel laminated siltstones (Stukel, 1987). Near the contact with the Cleveland Shale, the Chagrin at Brecksville exhibits several thin, horizontal, discontinuous pyrite beds. Pyrite is abundant in other forms near the contact, and is manifested in concretions, as nodules, as coatings on fossil molds, and as vertical burrow fillings. Brachiopods at Brecksville occur throughout the shales and at the bases and tops of many of the siltstone beds. Fossils are generally not found within the siltstones themselves.

In contrast, the Chagrin Shale at Brandywine Falls measures about 10 m in thickness, and consists of bluish-gray shales with interbedded, discontinuous siltstones. Siltstones exhibit current-rippled, cross-laminated bedding, plane-parallel bedding, and very gentle hummocky cross-stratification. At Brandywine the types of pyrite found at Brecksville are typically absent. Pyrite occasionally occurs as coatings on brachiopod molds. Brachiopods at Brandywine are distributed throughout the shales, and at the bases and tops of some siltstone beds. Again, fossils are rare within the siltstones.

In general, the units within the Chagrin at the Brecksville Reservation and Brandywine Falls sites cannot be correlated on the basis of lithology. The discontinuous nature of the siltstone beds, and the absence of horizontal pyrite layers at Brandywine Falls preclude using these parameters for correlation. There is no distinctive bedding feature of the shales or siltstones that permits a bed to bed correlation between sections. Some patterns of faunal distribution only provide an approximate correlation between the two sections. Therefore the two sections must be correlated using the Chagrin Shale-Cleveland Shale contact as a datum, even though it is erosional in nature. Any differences in elevation between the two sites, which are approximately 9 km apart, might be explained in terms of regional dip and/or differential rates of erosion at the sites. The effect of regional dip is minimized because the two sections are in close proximity.

Methods

Two sections in the Cuyahoga River Valley were sampled to determine the stratigraphic distribution of brachiopods and bivalves (Figures 2 and 3). Each section was trenched and sampled on a bed by bed basis using a pocket knife to remove individual shale and siltstone units. The trench at Brecksville Reservation exposed approximately 6 m of section, while the trench at Brandywine Falls exposed approximately 10 m of section. The trenched surface area averaged 20 cm by 30 cm. At each level where brachiopods and bivalves were discovered, collections were made, fossil orientation noted, and distance from the datum was measured. No attempt was made to determine numerical abundance at each level. Rather, generic identification and stratigraphic position were the primary goals.

Paleontology

Preservation

The Chagrin Shale megafauna in the Cuyahoga Valley consists almost exclusively of brachiopods, but includes a number of bivalves as well. Original shell material and internal structures of brachiopods are often preserved, notably of the spiriferids, orthids, and inarticulates.

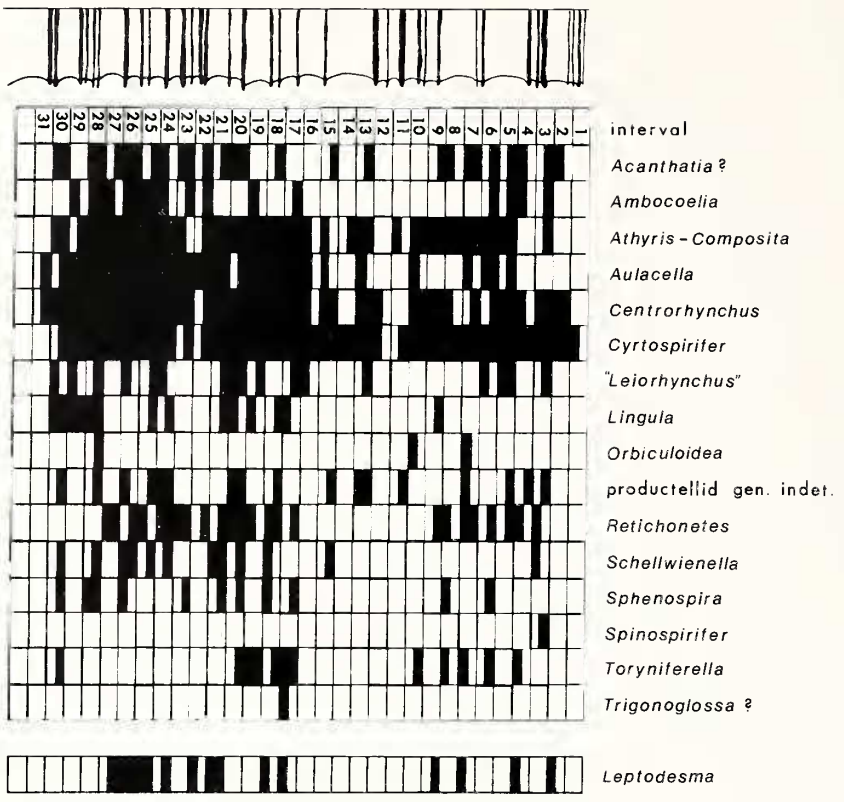
Densities of fossils in the Chagrin vary; often a bedding surface will contain clusters of one or two species, or randomly spaced taxa, and other surfaces may be barren. The degree of valve articulation is moderate, and the degree of fragmentation is low. Many specimens occur in life position, while others occur in more hydrodynamically stable positions.

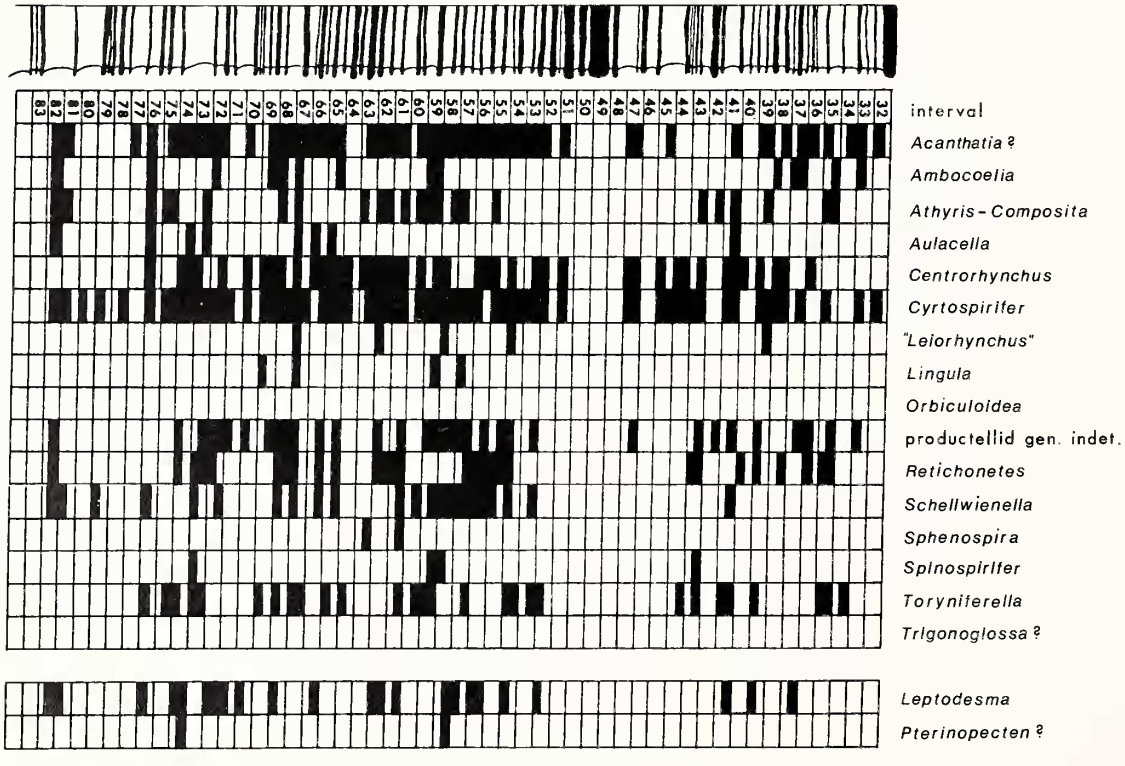
Some fossils have original shell material preserved so that delicate ornamentation is visible. Others are well-preserved molds of the interior, exhibiting muscle scars and other structures. However, most of the brachiopods are characterized by poorly preserved molds of the interior. Juvenile and adult stages were observed in most species. Evidence of predation is lacking, and epibionts are rare.

In some forms, shell material is absent, and molds of the exterior are rare. Sometimes critical characters, such as cardinalia and interareas, are not available for identification. While some of this may be due to selective positioning after death, or to some disarticulation and fragmentation in the normal course of events between storm activities, diagenesis should also be considered. Rapid burial may be responsible for a variety of chemical reactions, including skeletal dissolution, pyritization, and phosphatization of some faunal elements.

In the Chagrin brachiopods, skeletal material is often dissolved, leaving only molds or casts. Burial in organic rich muds often accelerates dissolution (Brett and Baird, 1986), probably due to the acidic nature of the sediments.

Pyrite assumes a variety of forms in the Chagrin Shale, including concretions, nodules, burrow infillings, and thin coatings on fossil molds. Since most bottom waters contain some dissolved oxygen, Berner (1984) indicated that pyrite usually precipitates in anoxic environments below the sediment-water interface. During periods of rapid burial, organic material is exposed to interstitial waters rich in reactive iron compounds. Together, these are subject to sulfate reduction by anaerobic bacteria, and pyrite is formed. In some of the Cuyahoga Valley brachiopods, pyrite occurs as thin coatings or as crystals encrusting fossil molds. From the sporadic occurrence of pyrite associated with fossils, it can be concluded that anaerobic microenvironments were locally present in the sediments.





FIGURES 2 (BRECKSVILLE) AND 3 (BRANDYWINE FALLS). *Distribution patterns of taxa at Chippewa Creek, Brecksville Reservation, and at Brandywine Creek, Brandywine Falls, respectively. Black intervals represent siltstones, and white intervals represent shales. Twenty-cm sample intervals are indicated directly to the right of the stratigraphic column.*

It must be noted that several thin (<1 cm), horizontal pyrite layers were found near the erosional Chagrin Shale-Cleveland Shale contact at Brecksville Reservation. The topmost of these is the Skinner's Run pyrite bed, also found elsewhere in the Chagrin outcrop area, at the contact with the overlying black Cleveland Shale. Pyritized material was exhumed and reworked during periods of erosion on normally anaerobic sea floors (Zagger and Banks, 1989). The Skinner's Run pyrite bed may, in turn, be analogous to the Leicester Pyrite Member, which is associated with a regional unconformity (Baird and Brett, 1986).

Phosphatic concretions are sometimes found in the Cuyahoga Valley, but can be found in much greater numbers at numerous sites in the central and eastern sections of the Chagrin outcrop area (Schwimmer et al., 1987). Manheim et al. (1975) listed conditions necessary for formation of modern marine phosphorite. These included: sediments with high TOC (total organic carbon) associated with dysaerobic waters, low rates of sedimentation and a low volume of calcium carbonate in sediments. Slansky (1986) noted that certain modern phosphates result from the reworking and concentration of existing phosphatic bioclasts, such as inarticulate brachiopod shells, arthropod remains, or bone fragments. Apatite precipitation may be triggered at one or more "nucleation sites," which initially become coated with humic acids. Phosphate precipitation is catalyzed by the acids, and not directly by the phosphatic surface of the organism. Once the process is initiated, precipitation continues, due to the lateral diffusion of ions from interstitial waters. Wetzel (1983, p. 264) stated that, if sediments are anoxic, phosphates may be released from sediments, diffused into surface waters and, over time, would be lost. However, if an oxidized zone is present near the sediment-water interface, then phosphate could be reduced by ferrous iron and precipitated as ferric phosphate and by absorption onto ferric hydroxide and calcium carbonate (Wetzel, 1983, p. 261-3).

Phosphate formation is favored by rapid burial of organic material, followed by long periods of little or no sedimentation (Brett and Baird, 1986). Wet chemical tests and analysis by energy-dispersed x-rays (EDX) have determined that concretions found in the Chagrin are phosphatic. The surrounding silts and shales tested negative for phosphorus. Generally, phosphatic material such as lingulid brachiopod shells, arthropod remains, and fish fragments acted as nucleation sites for phosphate formation in Chagrin concretions. EDX analyses also showed that non-phosphatic material in the concretions, such as pelmatozoan fragments, and the matrix itself, are enriched in phosphate (Joseph Hannibal, pers. comm.).

In summary, the Chagrin brachiopods show varying qualities of preservation. Some display shell material and delicate internal structures. Others are less well preserved, and are oriented so that vital identifying characters are either absent or obscured. Often molds are the only evidence of ancient life, and these cannot always be removed from the surrounding matrix to expose undersurfaces. The unbroken, articulated appearance of many of the specimens, as well as their orientation, distribution, and density, is evidence for quiet water conditions, with periodic burial of life assemblages by storm sediments. Chemical alteration includes shell dissolution, pyrite formation in local anaerobic microenvironments, and phosphatization during times of low sedimentation, after episodes of rapid burial.

Summary of taxa

The Cuyahoga Valley Chagrin fauna consists predominantly of brachiopods, with fewer bivalves. The description of taxa is designed not as a formal systematic description of the fauna, but as a guide for identification. The most important diagnostic features are presented along with remarks about preservation, distribution, and comparisons with similar taxa. The vertical distribution of brachiopods and bivalves at Brecksville Reservation and at Brandywine Falls are shown in Figures 2 and 3, respectively. The black intervals in each stratigraphic section represent silts, while the white intervals represent shales. For ease in charting distributions, each stratigraphic section was arbitrarily divided into consecutively numbered 20-cm intervals, shown to the right of each column. Distribution patterns discussed for each taxon will refer to these figures.

All figured specimens are deposited in The Cleveland Museum of Natural History (CMNH). The remainder of the material from this study is deposited in the paleontology collection in the Department of Geology at Kent State University (KSU).

Six orders of brachiopods have been identified in the Upper Devonian Chagrin Shale of the Cuyahoga Valley. The Inarticulata are represented by Lingulida and Acrotretida, while the Articulata are represented by Orthida, Strophomenida, Rhynchonellida, and Spiriferida. Four taxa of bivalves, representing three orders, are also presented.

Systematic paleontology

Phylum BRACHIOPODA Duméril, 1806
Class INARTICULATA Huxley, 1869
Order LINGULIDA Waagen, 1885
Superfamily LINGULACEA Menke, 1828
Family LINGULIDAE Menke, 1828
Genus *LINGULA* Bruguière, 1797
LINGULA ERIENSIS Girty, 1939
Figures 4.5a, b, 4.6

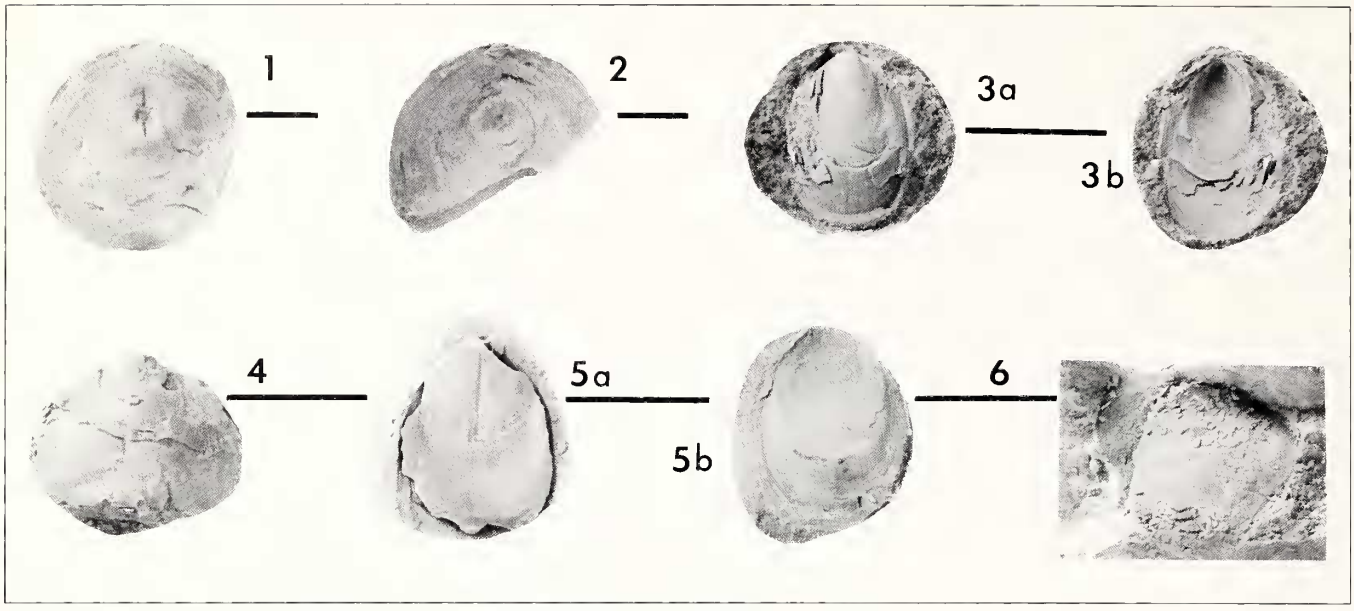


FIGURE 4. *Inarticulata.* 1-2, Orbiculoidea *sp.* 1, *pedicle interior, Mill Creek, KSU 4899;* 2, *mold of brachial valve interior, Brecksville Reservation, interval 6, CMNH 8401;* 3a,b, Lingula arcta, *partially exfoliated pedicle valve in concretion, Brandywine Falls, interval 59, CMNH 8402;* 4, Trigonoglossa *sp., partial pedicle valve, Brecksville Reservation, interval 17, CMNH 8403;* 5-6, Lingula eriensis. 5a,b, *partially exfoliated specimen in concretion, Brandywine Falls, interval 67, CMNH 8404;* 6, *specimen found in living position, valves splayed, Brecksville Reservation, interval 20, CMNH 8405. Bar scale = 1 cm.*

Description of material

Shell medium size, ovate, anterior end rounded, posterior end slightly pointed. Length approximately 1.2-1.5 times width. Valves generally flat, slightly biconvex in umbonal regions. Lateral margins rounded. Surface ornamentation consists of irregularly spaced growth lines, and very faint radial striations. Exfoliated specimens show alternating chitinous and phosphatic shell layers. Chitinous shell layers marked by closely spaced, regular, concentric lines of a different character from the external growth lines. Pedicle valve interior with cordate visceral area highlighted by curved, transverse striations. Central muscle scars ovate. In some specimens, pedicle groove is seen at posterior end. Brachial valve interior displays median ridge which extends almost entire length of shell. Muscle scars not visible.

Remarks

Lingulids are rare and occur either as sets of splayed valves in the shales (Figure 4.6), or in concretions in the siltstones. Although original shell material is present, often it is only partially preserved, and internal structures cannot be seen. Lingulids are far more common in the eastern part of the Chagrin outcrop area, where sediments are coarser. The burrowing lifestyle of lingulids is more suitable to coarser sediments than to fine grained muds (Thayer and Steele-Petrović, 1975). The low bulk density of lingulids would cause them to float on a fluid substrate, unable to assume their normal feeding position. Lingulids were most abundant in the lower half of both the Brecksville Reservation and Brandywine Falls sections (Figures 2 and 3). Girty (1939) reported *L. eriensis* and *L. arcta* Girty from the Chagrin Shale at Brecksville Reservation. However, the two species of *Lingula* found at these study sites cannot always be distinguished in the field, therefore distribution patterns outlined in Figures 2 and 3 reflect generic and not species patterns.

LINGULA ARCTA Girty, 1939
Figures 4.3a, b

Description of material

Small size, elongate oval outline, length greater than width. Lateral margins parallel. Surface ornament consists of very fine, evenly spaced, concentric growth lines. Pedicle valve umbo elevated posteriorly, and slightly pointed. Brachial valve and valve interiors unknown.

Remarks

One good specimen of a partially exfoliated pedicle valve was recovered from an in situ concretion at the Brandywine Falls section (Figure 4.3). Girty (1939) identified this species from the Chagrin Shale at Brecksville Reservation, and noted that it often occurred with *L. eriensis*. He stated that the two species were distinct, based upon shape and surface ornamentation. Growth lines on *L. arcta* are very fine and closely spaced,

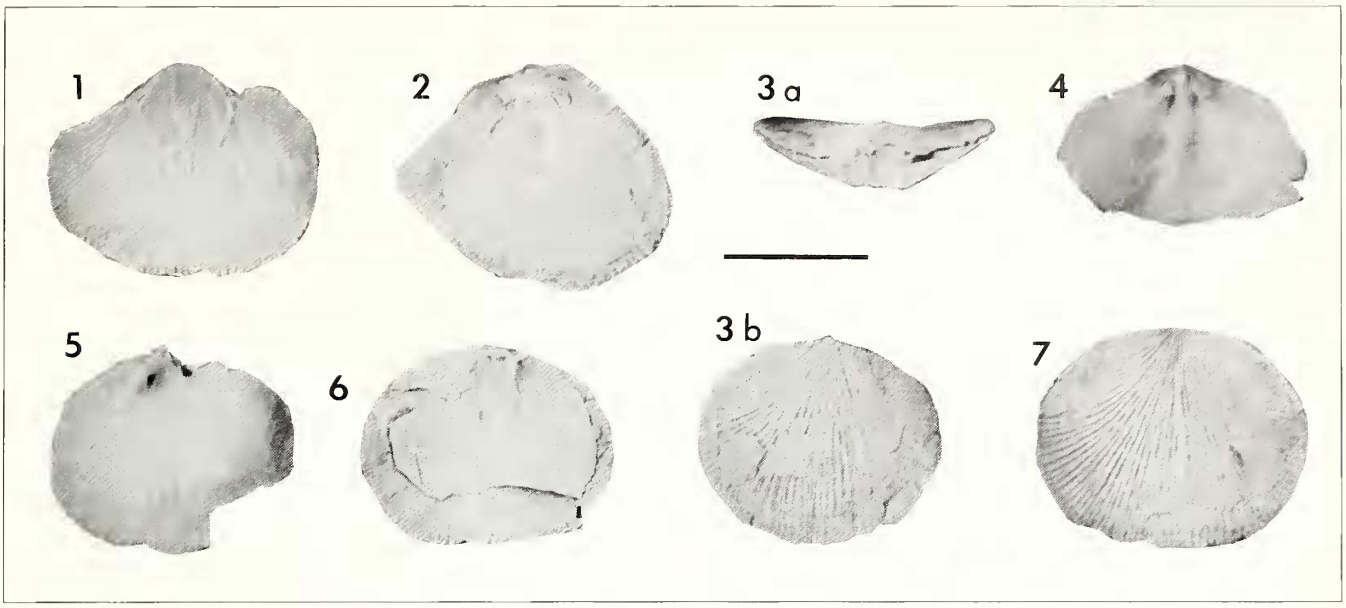


FIGURE 5. Aulacella *sp.* 1, *interior, pedicle valve, Brecksville Reservation, interval 28, CMNH 8406;* 2, *interior mold of brachial valve, Brecksville Reservation, interval 27, CMNH 8407,* 3a,b, *posterior view, and brachial valve exterior, Brecksville Reservation, float, CMNH 8408;* 4, *brachial valve interior, Brecksville Reservation, interval 26, CMNH 8409;* 5, *pedicle valve interior, Brecksville Reservation, float, CMNH 8410;* 6, *interior mold of pedicle valve, Brecksville Reservation, interval 28, CMNH 8411;* 7, *pedicle valve exterior, Brecksville Reservation, float, CMNH 8412. Bar scale = 1 cm.*

while those on *L. eriensis* are coarser, farther apart, and less regular. Girty (1939) also reported shell fragments of what could be *L. limatula* from the Chagrin Shale at Brecksville. The latter species is characterized by a markedly papillose shell surface. Neither of the lingulids collected from the Chagrin Shale in this study exhibit this character.

Genus *TRIGONOGLOSSA* Dunbar and Condra, 1932
TRIGONOGLOSSA sp.
Figure 4.4

Description of material

Shell medium size, triangular outline, gently convex pedicle valve, brachial valve unknown. Posterior end pointed. Length greater than width; greatest width in anterior part of specimen. The axial region of the specimen appears to be inflated, forming a gentle fold. Valve surface marked by strong, evenly spaced, concentric lines prominently elevated above surface of the valve, separated by flat interspaces. Very faint radial striations. Valve interiors unknown.

Remarks

One partial, somewhat crushed specimen was recovered from Brecksville Reservation. The prominent growth lines and triangular shape distinguish it from species of *Lingula*.

Order ACROTRETIDA Kühn, 1949
Suborder ACROTRETIDINA Kühn, 1949
Superfamily DISCINACEA Gray, 1840
Family DISCINIDAE Gray, 1840
Subfamily ORBICULOIDEINAE Schuchert, 1929
Genus *ORBICULOIDEA* d'Orbigny, 1847
ORBICULOIDEA sp.
Figures 4.1, 4.2

Description of material

Small to large size, circular outline, convex brachial valve, concave pedicle valve. Brachial valve apex pointed, posteriorly eccentric; diameter of figured specimen (Figure 4.2) approximately 3.2 cm. Ornament includes strong, elevated, evenly spaced, concentric growth lines. Smooth, wide depressions separate growth lines. Very faint radial striations are present, especially in the apical area, dying out anteriorly. Posterior margin rounded, not truncated. Muscle scars and other internal structures not observed.

Remarks

Three occurrences of *Orbiculoidea* were noted only in the section at Brecksville (Figure 2). One partial brachial valve, found atop a silt bed, was complete enough for identification. In contrast, Weidner (1983) found many well preserved orbiculoids in concretions in other parts of the Chagrin outcrop area. The pedicle valve of one such specimen from Mill Creek is illustrated (Figure 4.1) for comparison. The

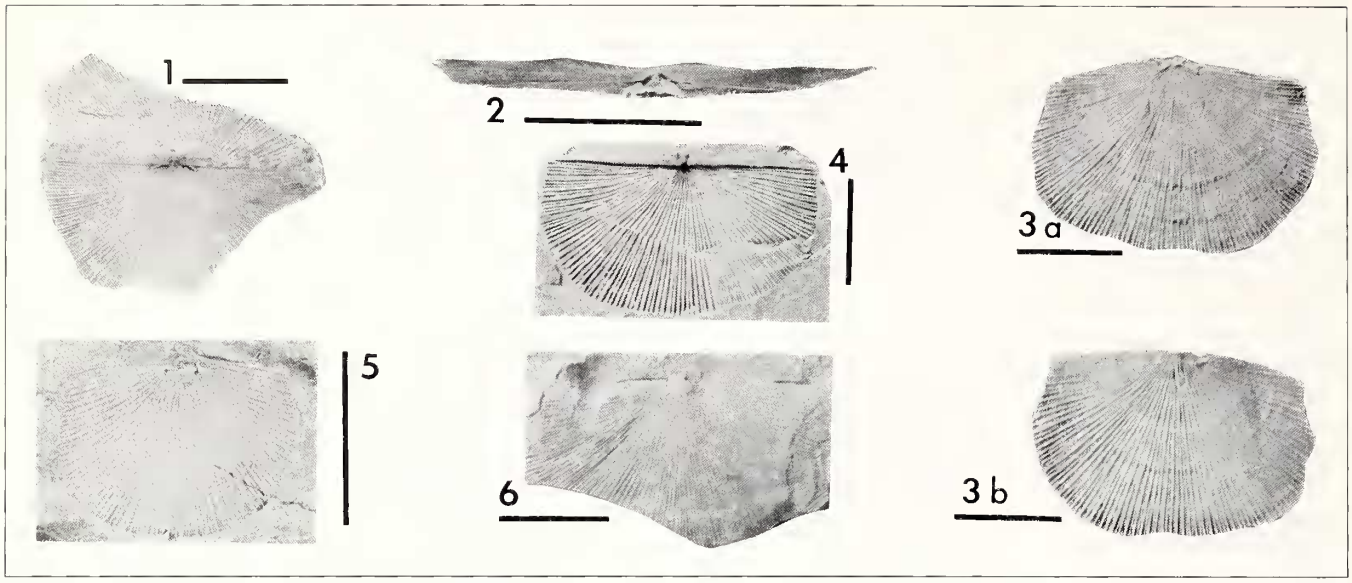


FIGURE 6. Schellwienella *sp.* 1, *interior mold of pedicle valve, with dental plate impressions, Brandywine Falls, interval 57, CMNH 8413;* 2, *posterior mold of interarea, deltidium and dental plates, Brandywine Falls, float, CMNH 8414;* 3a,b, *interior mold of pedicle valve, brachial valve, Brandywine Falls, float, CMNH 8415;* 4, *interior mold of pedicle valve and interarea, Brandywine Falls, float, CMNH 8416;* 5, *interior mold of pedicle valve, Brandywine Falls, interval 58, CMNH 8417;* 6, *interior mold of brachial valve, cardinal process, Brecksville Reservation, interval 24, CMNH 8418. Bar scale = 1 cm.*

size, shape, and ornamentation appear to closely resemble the Brecksville specimen (Figure 4.2). Pedicle foramen is narrow, linear; 8 mm length; posteriorly located with respect to the apex. Internal structures unknown.

Class ARTICULATA Huxley, 1869
Order ORTHIDA Schuchert and Cooper, 1932
Suborder ORTHIDINA Schuchert and Cooper, 1932
Superfamily RHIPIDOMELLACEA Alichova, 1960
Family ONNIELLIDAE Öpik, 1933
Genus *AULACELLA* Schuchert and Cooper, 1931
AULACELLA sp.
Figures 5.1-5.7

Description of material

Small subcircular shell; valves unequally biconvex; width greater than length; maximum width at mid-valve; hinge narrow, short, approximately half width of shell; delthyrium open; valve surfaces finely costellate; costellae extend from beak to anterior margin, and increase by intercalation; pedicle valve fold and brachial valve sulcus strong posteriorly, becoming weak anteriorly; anterior margin rectimarginate; valves inflated in areas of umbones, flattening laterally and anteriorly. Concentric ornamentation present near anterior margin. Pedicle valve interior with large, flabellate diductor muscle scars, which almost enclose small, spatulate adductor scars; a forked myophragm is seen anteriorly, separating diductor scars. Brachial valve interior with prominent, trilobed, cardinal process, and diverging brachiophore bases beneath elongate socket ridges; posterior flabellate, and anterior subquadrate, adductor muscle scars located on either side of dorsal fold.

Remarks

Aulacella can be distinguished from *Cariniferella* by the presence in the latter of a convexo-concave profile, a sharp fold, and a deep, narrow, sulcus (Schuchert and Cooper, 1932). Although Prosser (1912) reported species of *Cariniferella* in the Chagrin, none was found in this study. *Aulacella* is ubiquitous in the lower half of the Chagrin at Brecksville, decreasing in numbers and in occurrence in the upper half. In contrast, *Aulacella* is less abundant and is found in only seven intervals in the lower third of the section at Brandywine Falls, and in only one instance in the upper third (Figures 2 and 3). *Aulacella* is the only punctate taxon of Chagrin brachiopods. This feature may have enabled it to respire at reduced capacity, even when valves were shut during episodes of turbulence, which would normally clog the lophophore (Thayer, 1986; Shumway, 1982).

Order STROPHOMENIDA Öpik, 1934
Suborder STROPHOMENIDINA Öpik, 1934
Superfamily DAVIDSONIACEA W. King, 1850
Family MEEKELLIDAE Stehli, 1954
Subfamily MEEKELLINAE Stehli, 1954
Genus *SCHELLWIENELLA* I. Thomas, 1910
SCHELLWIENELLA sp.
Figures 6.1-6.6

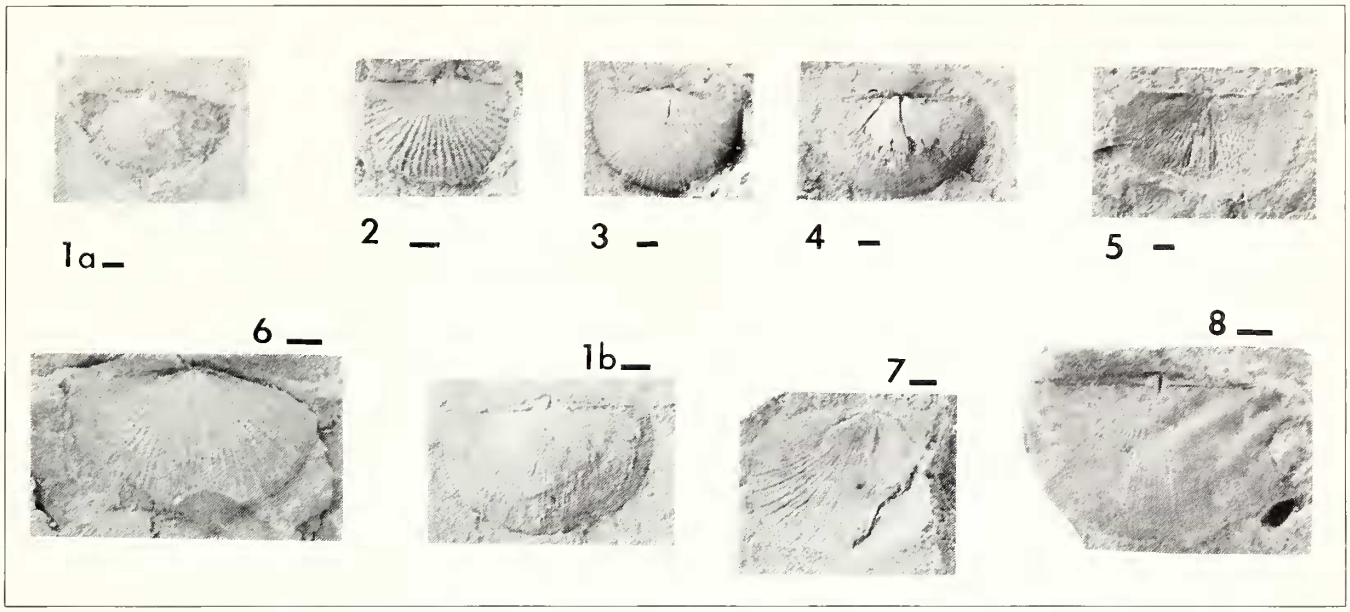


FIGURE 7. Retichonetes *sp.* 1a,b, *partially exfoliated brachial valve with four hinge spines on either side of pedicle valve umbo, and enlarged view of pedicle valve interarea, Brecksville Reservation, float, CMNH 8419;* 2, *interior mold of pedicle valve, with costellae and growth lines creating reticulated appearance, Brandywine Falls, interval 59, CMNH 8420;* 3, *interior mold of brachial valve, median septum, Brandywine Falls, interval 73, CMNH 8421;* 4, *partially exfoliated, pyritized brachial valve and pedicle valve spines, Brandywine Falls, interval 62, CMNH 8422;* 5, *interior mold of pedicle valve, flabellate diductor scars, divergent dental plates, Brecksville Reservation, interval 19, CMNH 8423;* 6, *interior mold of brachial valve, Brecksville Reservation, interval 23, CMNH 8424;* 7, *mold of brachial valve, median septum, alveolus, and divergent lateral septa, Brandywine Falls, interval 73, CMNH 8425;* 8, *mold of brachial valve interior, pedicle valve interarea, Brecksville Reservation, interval 23, CMNH 8426. Bar scale = 1 mm.*

Description of material

Small to medium size, semicircular outline, slightly resupinate profile; width greater than length. Valves generally flat, slightly convex in umbonal regions; hinge width slightly less than greatest shell width, which occurs at mid-length. Interarea straight, relatively high; triangular delthyrium covered by convex pseudodeltidium. Pedicle and brachial valves finely costellate; costellae increase by intercalation, and appear to curve gently as they approach posterior lateral margins; concentric ornamentation sparse. Fold and sulcus either weak or absent; anterior margin rectimarginate. Pedicle valve interior exhibits short dental plates diverging at wide angles; diductor muscle scars faint, large, flabellate. Brachial valve interior with small, bilobed, cardinal process, thin, short median ridge, bisecting slender, spatulate, adductor muscle scar.

Remarks

Schellwienella is distinguished from *Schuchertella* by the presence of short, diverging, dental plates. These plates are lacking in the latter genus. Most of the Chagrin specimens of *Schellwienella* are incomplete; generally the anterior and lateral margins are broken off, and original shell material is absent. In one specimen, however, (Figure 6.3a), the original shell material comprising the dental plates is present. A spirolophous lophophore was probable in all stocks of the superfamily Davidsoniacea, although impressions or calcareous supports are rare (Muir-Wood and Williams, 1965). *Schellwienella* is moderately abundant in the lower half of the Brecksville section, but occurs in only one interval in the upper half. At Brandywine Falls, this genus is more abundant, occurring in the lower two-thirds of the section, but with only one occurrence in the upper third of the site (Figures 2 and 3).

Suborder CHONETIDINA Muir-Wood, 1955
Superfamily CHONETACEA Bronn, 1862
Family CHONETIDAE Bronn, 1862
Subfamily DEVONOCHONETINAE Muir-Wood, 1962
Genus *RETICHONETES* Muir-Wood, 1962
RETICHONETES sp.
Figures 7.1-7.8

Description of material

Small size, semicircular outline; gently biconvex; width greater than length; hinge line straight, and equal to greatest width of shell; interareas moderately high; minimum of four spines project at high angles (45-60 degrees) from pedicle valve interarea, adjacent to umbo; delthyrium covered by pseudodeltidium. Valve exteriors

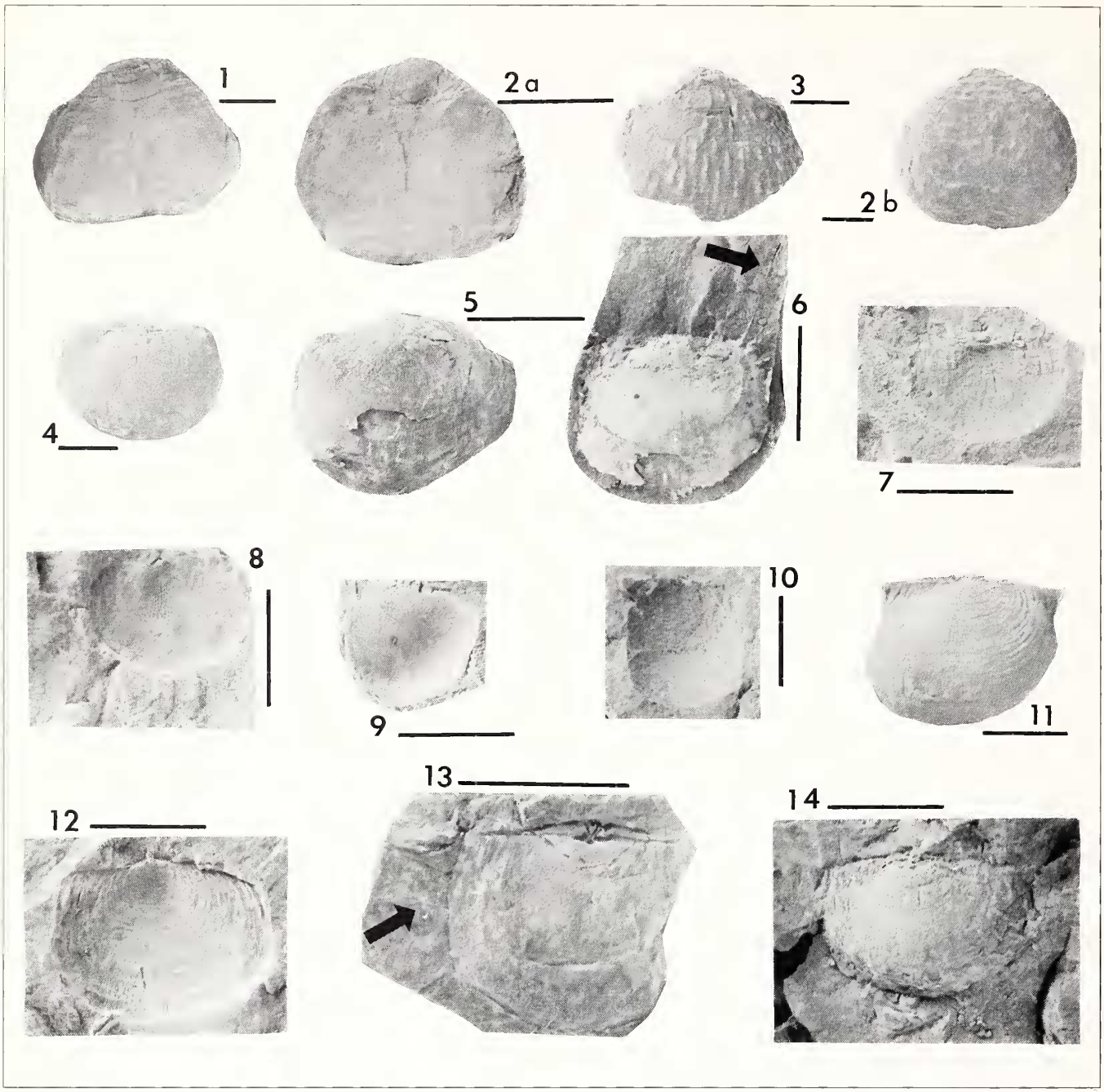


FIGURE 8. *Productellids.* 1-3, *Productellid, gen. indet.* 1, *interior mold of pedicle valve, sulcus, anterior rugae, Brandywine Falls, interval 57, CMNH 8427;* 2a,b, *interior mold of pedicle valve, with beak and divergent "septa", Brecksville Reservation, interval 24, CMNH 8428;* 3, *interior mold of pedicle valve, spine ridges, Brandywine Falls, float, CMNH 8429;* 4-14, Acanthatia *sp.* 4, *interior mold of brachial valve, Brecksville Reservation, interval 24, CMNH 8430;* 5, *interior mold of brachial valve, endospine impressions, Brandywine Falls, interval 58, CMNH 8431;* 6, *pedicle valve exterior, elongate hinge spines (arrow), prostrate body spines, borehole, Brecksville Reservation, interval 4, CMNH 8432;* 7, *mold of pedicle valve exterior, hinge and lateral spines, Brandywine Falls, float, CMNH 8433;* 8, *interior mold of brachial valve, cardinal process, breviseptum, Brandywine Falls, float, CMNH 8434;* 9, *Brachial valve exterior, spine impressions, Brecksville Reservation, interval 28, CMNH 8435;* 10, *exterior mold of pedicle valve, small ears, spine impressions, Brandywine Falls, interval 62, CMNH 8436;* 11, *interior mold of brachial valve, breviseptum, Brandywine Falls, float, CMNH 8437;* 12, *interior mold of brachial valve, bilobed cardinal process, endospine impressions, Brandywine Falls, float, CMNH 8438;* 13, *interior mold of brachial valve, alveolus; interior mold of pedicle valve interarea, pseudodeltidium, hinge spines, lateral spines (arrow), Brecksville Reservation, interval 27, CMNH 8439;* 14, *interior mold of pedicle valve, hinge spines, prostrate spines, Brecksville Reservation, float, CMNH 8440. Bar scale = 1 cm.*

capillate; capillae increase by intercalation; fold and sulcus absent; anterior margin rounded. Pedicle valve interior with short median septum, originating at posterior margin, and extending approximately one-fourth shell length; dental plates present, diverging at wide angle; diductor muscle scars large, flabellate. Brachial valve interior with small, lobate cardinal process; muscle scars small, slightly flabellate.

Remarks

Prosser (1912) reported and described *Chonetes minutus* Prosser, 1912 from the Chagrin Shale in Ashtabula County, and *Chonetes scitulus* Hall, 1857 from the Chagrin Shale at Tinker's Creek in Cuyahoga County. *Retichonetes* is differentiated from *Chonetes* by the reticulate appearance of the valves, and by the presence of an anterior median septum and two short lateral septa in the brachial valve, as opposed to three or more fine, long, diverging septa in the brachial valve of *Chonetes* (Muir-Wood, 1962). *Retichonetes* occurs throughout both of the measured sections (Figures 2 and 3).

Suborder PRODUCTIDINA Waagen, 1883
Superfamily PRODUCTACEA Gray, 1840
Family PRODUCTELLIDAE Schuchert, 1929
Subfamily PRODUCTELLINAE Schuchert, 1929
PRODUCTELLID gen. indet.
Figures 8.1-8.3

Description of material

Several medium size pedicle valves are not assignable to a genus or to a species. They retain the convex, subtrigonal, productellid shape, but an absence of brachial valves, interareas, and cardinalia preclude more specific identification. The inflated pedicle valve appears to be rugose anteriorly, and to be ornamented with evenly spaced spine ridges. The beak extends over the hinge area, and curves inward. Width is greater than length, with the greatest width at midlength. A mold of the exterior of the pedicle valve confirms the presence of ears. Although one specimen (Figure 8.1) has a prominent sulcus, a feature common in leioproductids, the lack of a median ridge ornamented with a spine row makes assignment to this group questionable. Another specimen (Figure 8.2b) has two converging "septa" originating at the umbo and extending down the center of the valve to midlength. Specimens of this taxon appear to be present, in small numbers, throughout both Brecksville and Brandywine Falls (Figures 2 and 3).

Subfamily CHONOPECTINAE Muir-Wood and Cooper, 1960
Genus *ACANTHATIA* Muir-Wood and Cooper, 1960
ACANTHATIA sp.
Figures 8.4-8.14

Description of material

Small to medium size, semicircular outline. Width greater than length. Hinge length slightly less that greatest width, which occurs at midlength. Pedicle valve moderately convex, brachial valve concave. Pedicle valve ears small, if present, and not differentiated from visceral disc. Pedicle valve interarea longer and higher than brachial valve interarea, and characterized by pseudodeltidium (Figure 8.13). Pedicle valve ornamented by evenly-spaced, concentrically arranged prostrate spines over surface, and long balancing or attachment spines at hinge. Pedicle valve slightly rugose, especially anteriorly. Brachial valve with depressions corresponding to pedicle valve spines (Figure 8.12). Pedicle valve interior often marked by very fine punctation, representing endospines. Brachial valve interior with bilobed cardinal process, and very thin breviseptum. Alveolus not well preserved. Interior surface marked by numerous, small endospines. Muscle scars not seen.

Remarks

Acanthatia is characterized by its semicircular outline, lack of costation, lack of spine ridges and distinct interarea in each valve. The finely punctate interior surfaces are evidence of endospines, which represent projections of the taleolae (pseudopunctae) into the body cavity. This genus occurs throughout both sections in this study. Prosser (1912) reported *Productella hirsuta* Hall, 1867 from the Chagrin Shale at Tinker's Creek, Cuyahoga County. *Productella* is characterized by suberect or recumbent spines which arise from scattered pustules (Muir-Wood and Cooper, 1960). The specimens in this study show no evidence of surface pustules. Further, spines are arranged in rows, and are not scattered.

Order RHYNCHONELLIDA Kühn, 1949
Superfamily RHYNCHONELLACEA Gray, 1848
Family TRIGONIRHYNCHIIDAE McLaren (in Schmidt and McLaren), 1965
Genus *CENTRORHYNCHUS* Sartenaer, 1970
CENTRORHYNCHUS sp.
Figures 9.1-9.12

Description of material

Small size, biconvex, rounded outline; length approximately equal to width; greatest height at midvalve. Ornament of simple, sharply angular costae, which arise in umbonal regions, and terminate at anterior margins. Costae internally thickened in axial regions, leaving a more rounded impression on interior molds. General costal formula 3/4; 1-1/0-0; 7+/8+ (Figure 9.1). Pedicle valve umbo inflated, beak slightly incurved over interarea. Pedicle valve sinus wide, beginning about midvalve, and

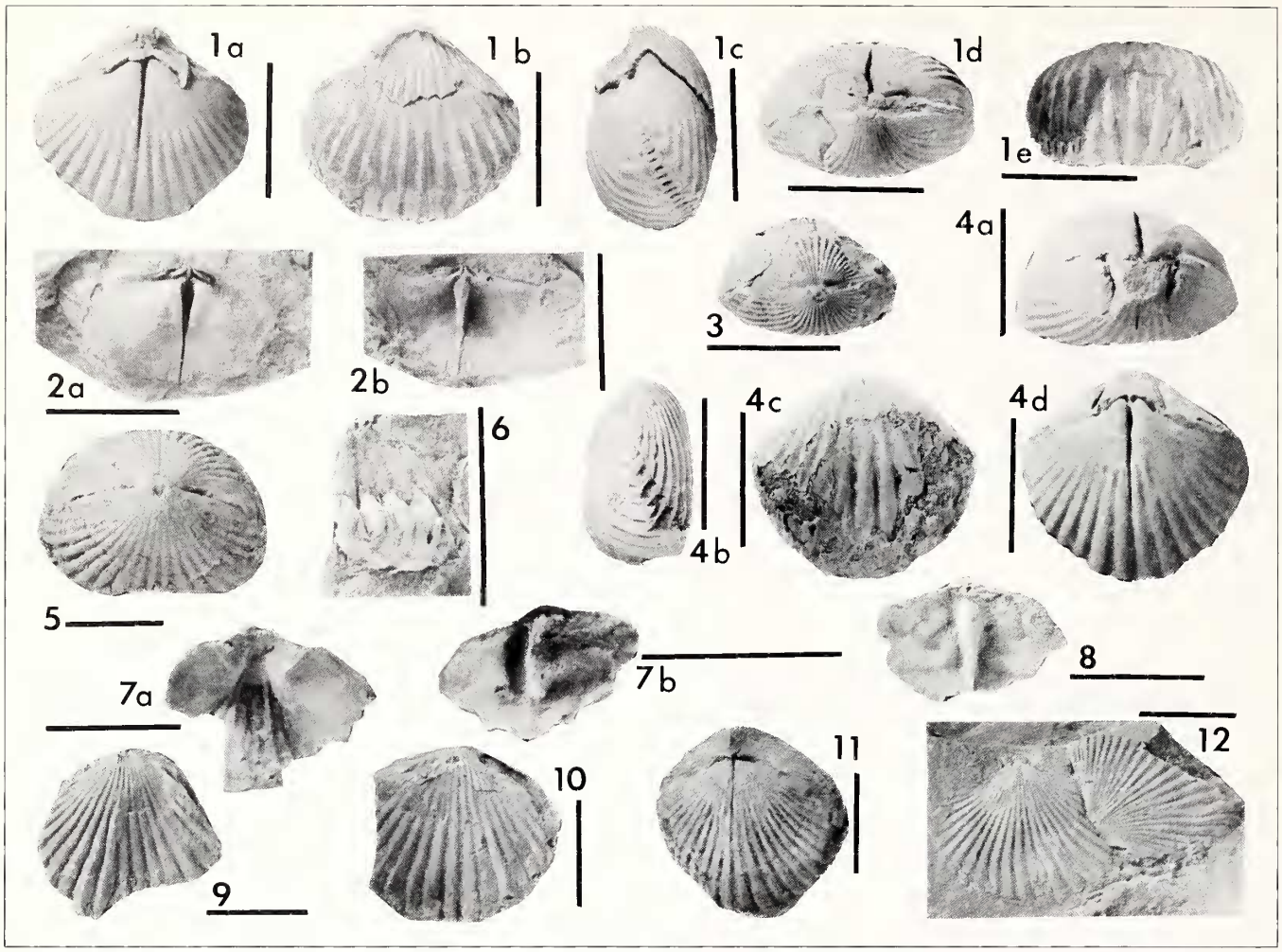


FIGURE 9. Centrorhynchus *sp.* 1a-e, *ventral, dorsal, lateral, posterior, and anterior views, Brecksville Reservation, interval 28, CMNH 8441;* 2a,b, *interior mold of brachial valve and latex mold of same specimen, Brandywine Falls, interval 39, CMNH 8442;* 3, *posterior view, Brecksville Reservation, interval 28, CMNH 8443;* 4a-d, *posterior, dorsal, lateral and ventral views, Brecksville Reservation, interval 28, CMNH 8444;* 5, *posterior view, pedicle foramen, Brecksville Reservation, float, CMNH 8445;* 6, *crenulate anterior margin, Brecksville Reservation, interval 28 ,CMNH 8446;* 7a,b, *pedicle and brachial valve interiors, Brecksville Reservation, interval 5, CMNH 8447;* 8, *brachial valve interior, Brandywine Falls, float, CMNH 8448;* 9, *mold of pedicle valve, Brandywine Falls, float, CMNH 8449;* 10, *mold of pedicle valve, Brandywine Falls, float, CMNH 8450;* 11, *interior mold of brachial valve, Brandywine Falls, float, CMNH 8451;* 12, *interior molds of pedicle and brachial valves, Brandywine Falls, float, CMNH 8452. Bar scale = 1 cm.*

extending to anterior margin. Tongue well-defined. Anterior margin crenulate (Figure 9.6). Pedicle valve interior with short dental plates. Brachial valve interior with covered, U-shaped septalium, strongly arched anteriorly (Figure 9.2). Septum stout, extending approximately one half shell length.

Remarks

Angular costae, a distinctive general costal formula, a robust septalium and cover, generally rounded outline, inflated pedicle valve, and suberect pedicle valve beak are diagnostic characters of the genus *Centrorhynchus*. Sartenaer (1970) pointed out that this Famennian genus appears in New York and Pennsylvania. Identification of the Chagrin Shale specimens would be reinforced if specimens in better condition could be recovered and serially sectioned. Distribution is shown in Figures 2 and 3. This rynchonellid is the most numerous and persistent taxon found in the study area.

Family CAMAROTOECHIIDAE Schuchert, 1929
Subfamily CAMAROTOECHIINAE Schuchert, 1929
Genus *LEIORHYNCHUS* Hall, 1860
"LEIORHYNCHUS" sp.
Figures 10.1-10.9

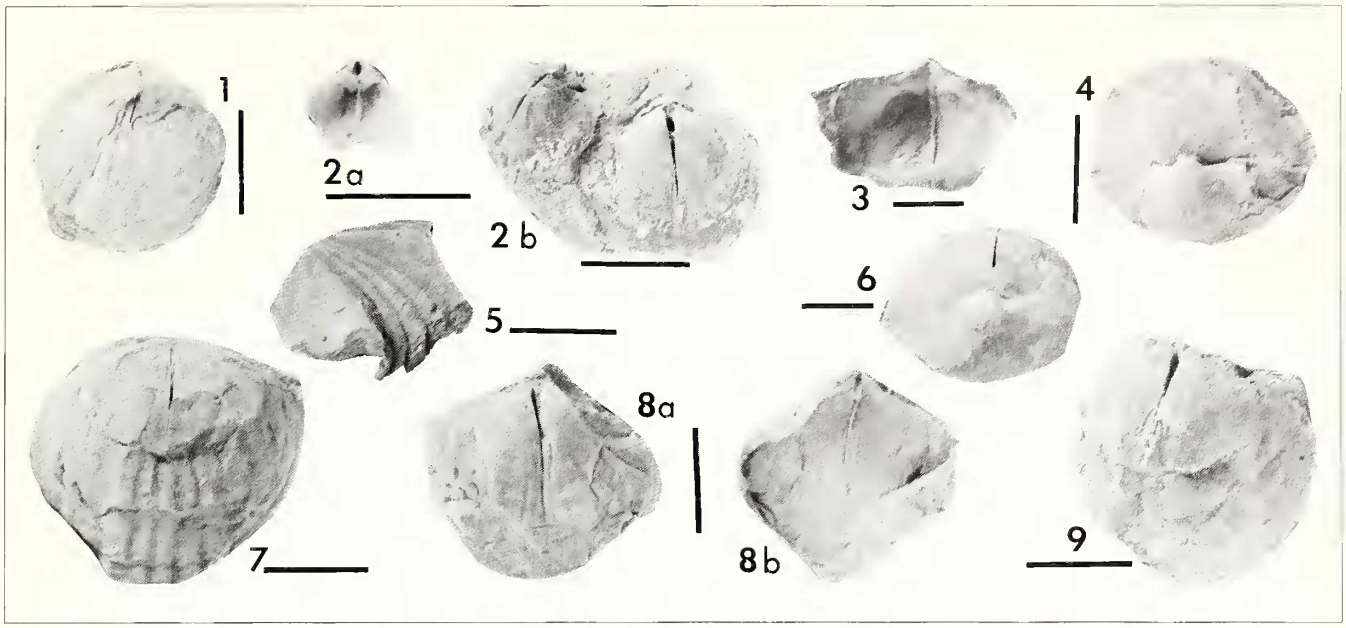


FIGURE 10. "Leiorhynchus" *sp.* 1, *interior mold of brachial valve, Brecksville Reservation, interval 5, CMNH 8453;* 2a,b, *interior of pedicle valve umbo and interior mold of pedicle valve and brachial valve, Brecksville Reservation, interval 5, CMNH 8454;* 3, *interior, brachial valve umbo, Brandywine Falls, float, CMNH 8455;* 4, *posterior view, Brecksville Reservation, interval 5, CMNH 8456;* 5, *antero-lateral mold of pedicle valve, Brecksville Reservation, float, CMNH 8457;* 6, *mold of posterior, Brandywine Falls, float, CMNH 8458;* 7, *interior mold of brachial valve, septum and muscle scars, Brecksville Reservation, interval 2, CMNH 8459;* 8a,b, *internal mold of brachial valve and latex mold of same specimen, Brecksville Reservation, interval 5, CMNH 8460;* 9, *interior mold of brachial valve, Brandywine Falls, float, CMNH 8461. Bar scale = 1 cm.*

Description of material

Medium size, biconvex, globular; outline circular. Pedicle valve beak strongly incurved and touching brachial valve. Pedicle foramen, if present, very small, and rounded. Pedicle sinus and brachial fold are weak and wide, originating from about midlength of the valve. The tongue is not visible. Surface ornament of a few coarse median costae which originate in umbonal regions and extend to anterior commissure. Brachial valve fold with at least five costae, pedicle valve sulcus with fewer. Costae on lateral slopes weak or absent. Pedicle valve interior with median septum extending one third shell length. Shell appears thickened in posterior region. Pedicle valve interior with short, divergent dental plates and robust teeth. Brachial valve interior with amphora-shaped septalium, with deep umbonal cavities on either side. Septum extends at least one half shell length.

Remarks

Prosser (1912) reported three species of *Liorhynchus (= Leiorhynchus)* from the Chagrin Shale of Lake County. Although *Leiorhynchus* is not considered a Famennian genus (Sartenaer 1967), preservation in the Chagrin specimens is too poor and features are too indistinct for a more concrete diagnosis. No complete, articulated specimens were found, and the general costal formula could not be determined. This taxon is fairly abundant at Brecksville Reservation, occurring throughout the section (Figure 2). On the other hand, at Brandywine Falls, *"Leiorhynchus"* was recovered from only four intervals (Figure 3). It is possible that this taxon appeared more frequently, but was unrecognizable due to conditions of preservation.

Order SPIRIFERIDA Waagen, 1883
Suborder ATHYRIDIDINA Boucot, Johnson, and Staton, 1964
Superfamily ATHYRIDACEA M'Coy, 1844
Family ATHYRIDIDAE M'Coy, 1844
Subfamily ATHYRIDINAE M'Coy, 1844
Genus *ATHYRIS* M'Coy, 1844
ATHYRIS sp.
Figures 11.1-5, 11.7

Description of material

Small to medium size, subcircular, biconvex, inflated in umbonal areas, flattened on lateral slopes and around anterior margin. Hinge length less than greatest width, which occurs at midvalve. Pedicle beak extends over hinge, and incurves slightly; foramen rounded, moderately large. Pedicle valve weakly sulcate, from about midvalve to anterior margin; ornament of concentric growth lines, some lamellose. Pedicle interior with divergent dental plates extending approximately one third shell length; spiralium impressed upon interior mold of one specimen (Figure 11.7).

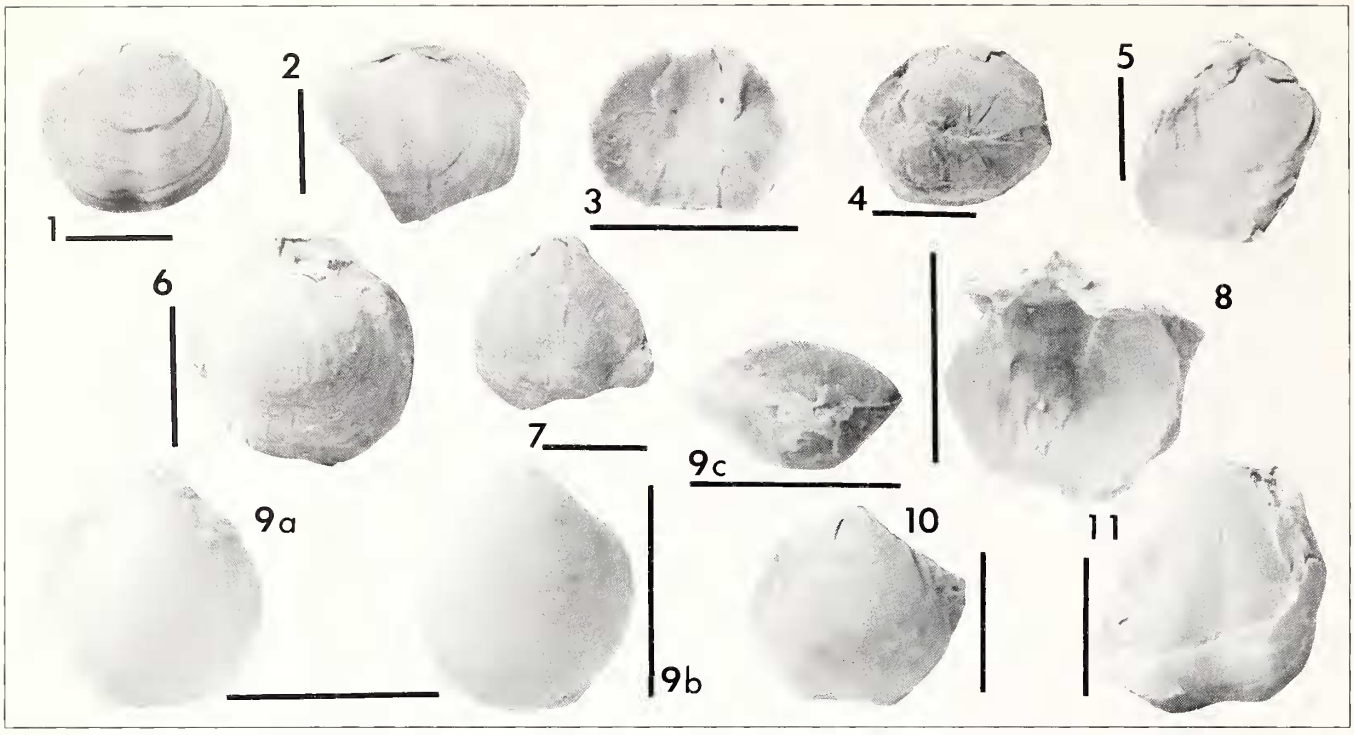


FIGURE 11. Athyris-Composita. 1-5,7, Athyris *sp.* 1, *pedicle valve exterior, dental plate impressions, Brecksville Reservation, interval 18, CMNH 8462;* 2, *interior mold of brachial valve, median septum and elongate muscle scar, Brandywine Falls, interval 59, CMNH 8463;* 3, *pedicle valve interior, dental plates, Brandywine Falls, float, CMNH 8464;* 4, *mold of posterior umbones, Brandywine Falls, float, CMNH 8465;* 5, *mold of brachial valve interior, median septum and elongate muscle scar, Brandywine Falls, float, CMNH 8466;* 7, *interior mold of spiralium, Brandywine Falls, float, CMNH 8468;* 6,8-11, Composita, *sp.* 6, *brachial valve exterior, Brecksville Reservation, interval 29, CMNH 8467;* 8, *pedicle valve interior, dental plates, chordate muscle scar, Brecksville Reservation, interval 28, CMNH 8469;* 9a-c, *dorsal, ventral, lateral interior molds, Brandywine Falls, float, CMNH 8470;* 10, *pedicle valve exterior, dental plates, Brecksville Reservation, interval 29, CMNH 8471;* 11, *interior mold of pedicle valve, chordate muscle scar, Brandywine Falls, float, CMNH 8472. Bar scale = 1 cm.*

Brachial valve interior with median septum extending half of shell length, bounded by thin, elongate muscle scars. Tooth sockets elongate.

Remarks

Athyris and *Composita* are members of the same subfamily, and externally, resemble one another. The former genus is more flattened laterally, and less convex overall than the latter. Differences between the two genera can be found internally, especially in the length and angle of divergence of the dental plates. Unfortunately, in the field, it is rare to be able to distinguish between the two genera, when weathered molds or fragments are the only material available. For this reason, *Athyris* and *Composita* are considered together when plotting occurrence at the two study sites (Figures 2 and 3). Both appear to be fairly abundant throughout the section at Brecksville Reservation. At Brandywine Falls, both are found in the lower half of the unit, and occur again sporadically in the upper third.

Genus *COMPOSITA* Brown, 1849

COMPOSITA sp.
Figures 11.6, 11.8-11.11

Description of material

Small to medium size, ovate, biconvex, length greater than width; maximum width at midvalve. Hinge line short. Ornament of concentric growth lines, becoming somewhat lamellose anteriorly; faint radial striations originate at beak and extend to margins. Pedicle valve with poorly defined fold; anterior margin appears uniplicate. Pedicle beak extends over hinge line; foramen rounded, open. Pedicle valve interior strong teeth supported by divergent dental plates, which extend about one fourth shell length, recurving slightly at the anterior ends. Muscle scars cordate (Figure 11.11). Brachial valve interior with median septum originating at beak and extending one half shell length, bounded by thin, elongate muscle scars (Figure 11.9a).

Remarks

Composita closely resembles *Athyris*, as pointed out in remarks about the latter taxon.

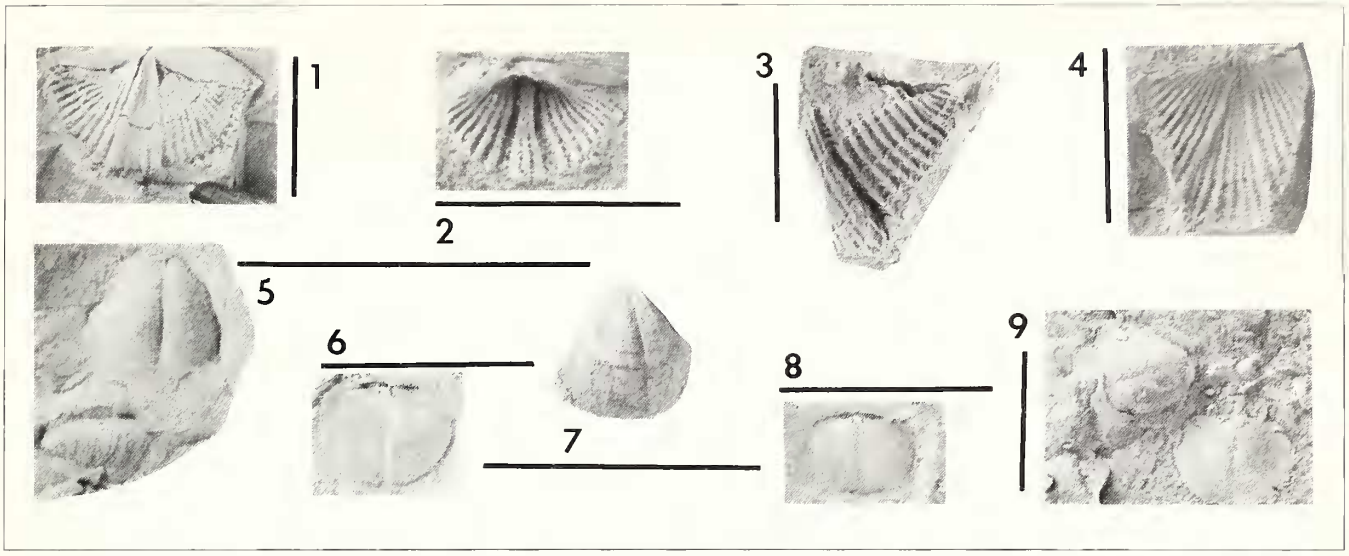


FIGURE 12. Spinospirifer *and* Ambocoelia. 1-4, Spinospirifer. 1, *pedicle valve mold, Brandywine Falls, interval 73, CMNH 8488;* 2, *interior mold of pedicle valve with punctae, Brandywine Falls, interval 59, CMNH 8473;* 3, *interior mold of pedicle valve, punctae, Brecksville Reservation, interval 3, CMNH 8474;* 4, *pedicle valve mold, Brandywine Falls, interval 43, CMNH 8475;* 5-9, Ambocoelia. 5, *latex mold of pedicle valve, Brecksville Reservation, interval 19, CMNH 8476;* 6, *interior mold of brachial valve, Brandywine Falls, interval 68, CMNH 8477;* 7, *interior mold of pedicle valve, Brandywine Falls, interval 58, CMNH 8478;* 8, *interior mold of brachial valve, Brecksville Reservation, interval 19, CMNH 8479;* 9, *interior mold of pedicle valve, and brachial valve interior, Brecksville Reservation, interval 5, CMNH 8480. Bar scale = 1 cm.*

Suborder SPIRIFERIDINA Waagen, 1883
Superfamily CYRTIACEA Fredericks, (1919) 1924
Family AMBOCOELIIDAE George, 1931
Genus *AMBOCOELIA* Hall, 1860
AMBOCOELIA sp.
Figures 12.5-12.9

Description of material

Small size, pedicle valve strongly convex, brachial valve weakly convex. Trigonal to subtrigonal outline; length greater than width; hinge line less than greatest width, which occurs at midvalve. Interareas not visible. Surface ornament of concentric growth lamellae, especially evident in the anterior part of the shell, as well as concentrically arranged spine rows. Pedicle valve with deep, narrow sulcus originating at beak and extending to rectimarginate anterior commissure. Posterior two-thirds of pedicle valve, and umbonal region, inflated; anterior third of valve, and lateral flanks, flattened. Brachial valve circular, with shallow sulcus extending from umbonal region to anterior margin; slightly inflated in posterior half of umbonal region; anterior half of valve, and flanks, flattened. Brachial valve interior with short divergent crura which are attached to socket ridges by hinge plates. Cardinal process small, triangular. Cardinal extremities rounded.

Remarks

A distinctive quadrate muscle pattern, described by Hall (1860), is characteristic of *Ambocoelia,* as well as a deeply triangular pedicle interarea. Very few specimens of this taxon were collected in the study area; unfortunately, neither of these features was exposed in the specimens collected, nor was the brachial valve muscle pattern. The taxon is common in the lower half of the section at Brecksville, but is sparse in the upper third. Distribution at Brandywine Falls is limited to the lower and upper thirds of the section (Figures 2 and 3).

Superfamily SPIRIFERACEA King, 1846
Family MUCROSPIRIFERIDAE Pitrat, 1965
Genus *SPINOSPIRIFER* Martynova, 1961
SPINOSPIRIFER sp.
Figures 12.1-12.4

Description of material

Transverse, rhomboidal shells. Ornament of simple plications; shell spinose. Pedicle valve with sulcus defined by one larger plication on either side, and at least three smaller plications on the sulcus. Pedicle valve interior with short, divergent dental plates. Brachial valve, interareas, and other internal structures unknown.

Remarks

A few specimens of this taxon were found to be spinose upon microscopic examination. Material was scarce, and consisted mostly of fragments, making identification difficult. It is possible that this taxon may be

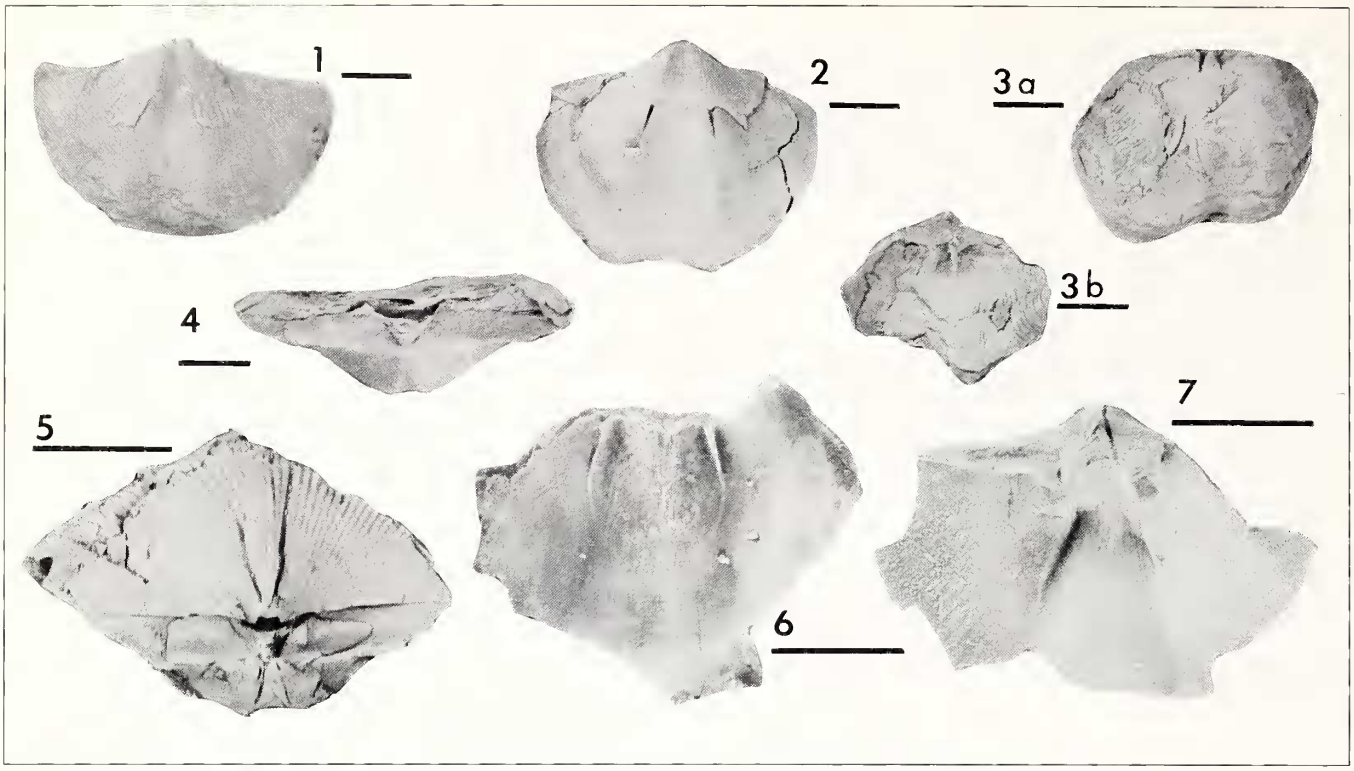


FIGURE 13. Cyrtospirifer leboeufensis. 1, *partially exfoliated pedicle valve, Brandywine Falls, float, CMNH 8481;* 2, *interior mold of pedicle valve, Brecksville Reservation, interval 11, CMNH 8482;* 3a,b, *interior mold of spiralium and counterpart, Brandywine Falls, interval 45, CMNH 8483;* 4, *posterior view, pedicle valve interarea, upper half of delthyrium covered, Brandywine Falls, float, CMNH 8484;* 5, *posterior view, interarea, Brecksville Reservation, interval 24, CMNH 8485;* 6, *pedicle valve interior, convergent dental plates, flabellate muscle scar, Brandywine Falls, float, CMNH 8486;* 7, *pedicle valve interior, Brandywine Falls, float, CMNH 8487. Bar scale = 1 cm.*

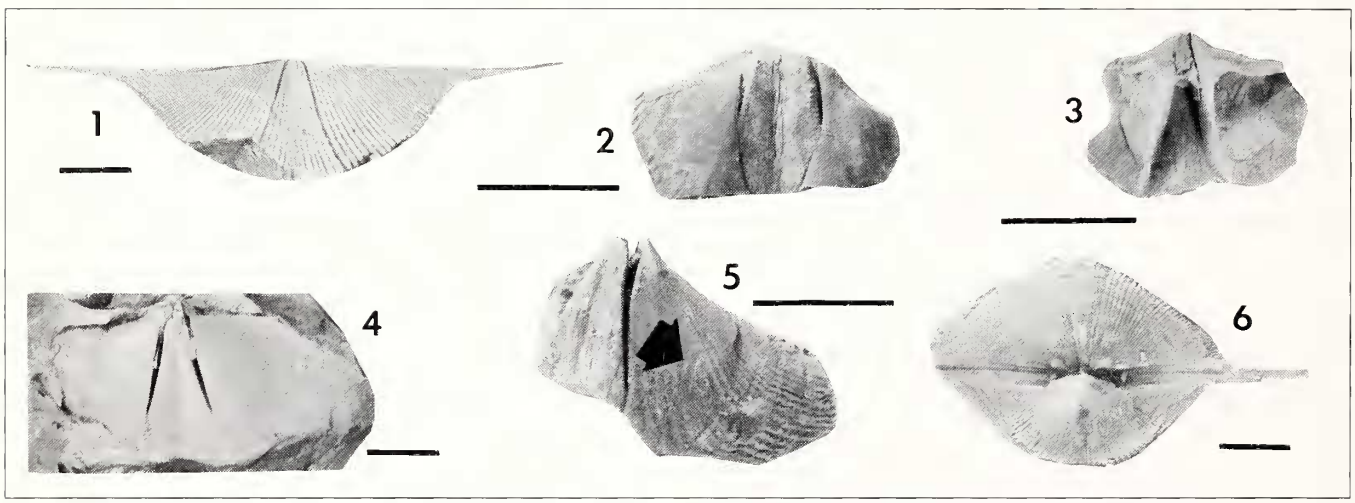


FIGURE 14. Cyrtospirifer spicatus. 1, *mold of pedicle valve exterior, elongate mucrons, Brandywine Falls, float, CMNH 8489;* 2, *partial mold of pedicle valve interior, divergent dental plates and spatulate muscle scar, Brandywine Falls, float, CMNH 8490;* 3, *pedicle valve interior, dental plates diverging at 45 degree angle, Brecksville Reservation, interval 28, CMNH 8491;* 4, *interior mold of pedicle valve, divergent dental plates, spatulate muscle scar, Brandywine Falls, float, CMNH 8492;* 5, *interior mold of pedicle valve, spiralium impression (arrow), Brandywine Falls, float, CMNH 8493;* 6, *posterior view of narrow interarea, Brandywine Falls, float, CMNH 8494. Bar scale = 1 cm.*

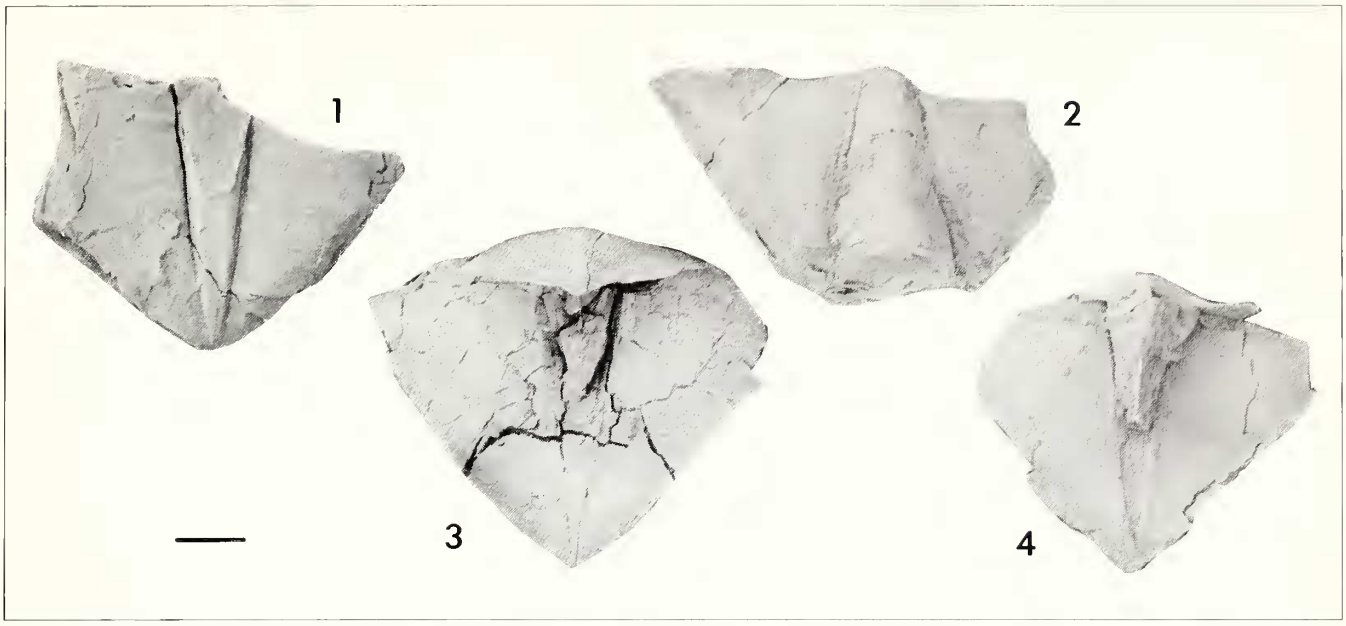


FIGURE 15. Sphenospira alta. 1, *interior mold of pedicle valve interaea with horizontal and vertical striations, delthyrium, stegidium, Brecksville Reservation, interval 21, CMNH 8495;* 2, *brachial valve exterior, Brecksville Reservation, interval 8, CMNH 8496;* 3, *interior mold of pedicle valve interarea, stegidium, Brecksville Reservation, interval 8, CMNH 8497;* 4, *interior mold of pedicle valve interarea, stegidium, Brecksville Reservation, interval 28, CMNH 8498. Bar scale = 1 cm.*

more abundant in the study area than reported, but due to the paucity of well-preserved material from the unit, may not have been identifiable. Partial molds and fragments are particularly difficult to identify.

Family CYRTOSPRIFERIDAE Termier and Termier, 1949
Genus *CYRTOSPIRIFER* Nalivkin (in Fredericks, 1924)
CYRTOSPIRIFER LEBOEUFENSIS Greiner, 1957
Figures 13.1-13.7

Description of material

Medium to large size; generally transverse; subpentagonal profile; unevenly biconvex, with pedicle valve slightly more inflated. Hinge line straight, equal to or slightly less than greatest width of shell; interareas moderately high, vertically striated; brachial interarea anacline, pedicle interarea apsacline; large, open, triangular delthyrium. Valve exteriors ornamented with low, rounded, costae which originate at beak and extend to anterior margin; lateral costae simple. Costae on fold and sulcus increase by bifurcation. External lamellae common on anterior half of shell. Pedicle valve exterior with greatest convexity in area of umbo; beak projects over hingeline; long, V-shaped sulcus is moderately deep on the posterior half of the valve, becoming shallow and even obsolete for the anterior half. Anterior margin gently uniplicate. Brachial valve exterior with a sharply defined fold originating at the beak and terminating at the anterior margin. Pedicle valve interior with pair of dental plates extending from the beak, initially diverging at a wide angle then recurving around the anterior end of the spatulate diductor muscle scar, which bears radial striations on the anterior two-thirds of its length. The adductor muscle scars are seen on a slender median groove, located between two low ridges on the diductor scar, which extends two-thirds the length of the shell. Spiral brachidia impressed upon the internal mold of the lateral mantle cavity in some specimens. The brachial valve interior not observed.

Remarks

Cyrtospirifer is particularly abundant and well preserved in the Chagrin Shale, and often original shell material can be recovered. The preservation of delicate dental plates suggests moderate to rapid burial, before disarticulation and breakage could occur. Greiner (1957) noted in *C. leboeufensis* that the pedicle valve dental plates join, forming a low ridge around the anterior portion of the diductor muscle scar. This ridge is not prominent in the Chagrin specimens. He further stated that this species is distinguished by its size, shape, and distinct, elongated muscle scar, which is partly enclosed by the dental plates (Figure 13.7). Prosser (1912) reported *Cyrtospirifer* from Brecksville Reservation and from Brandywine Falls.

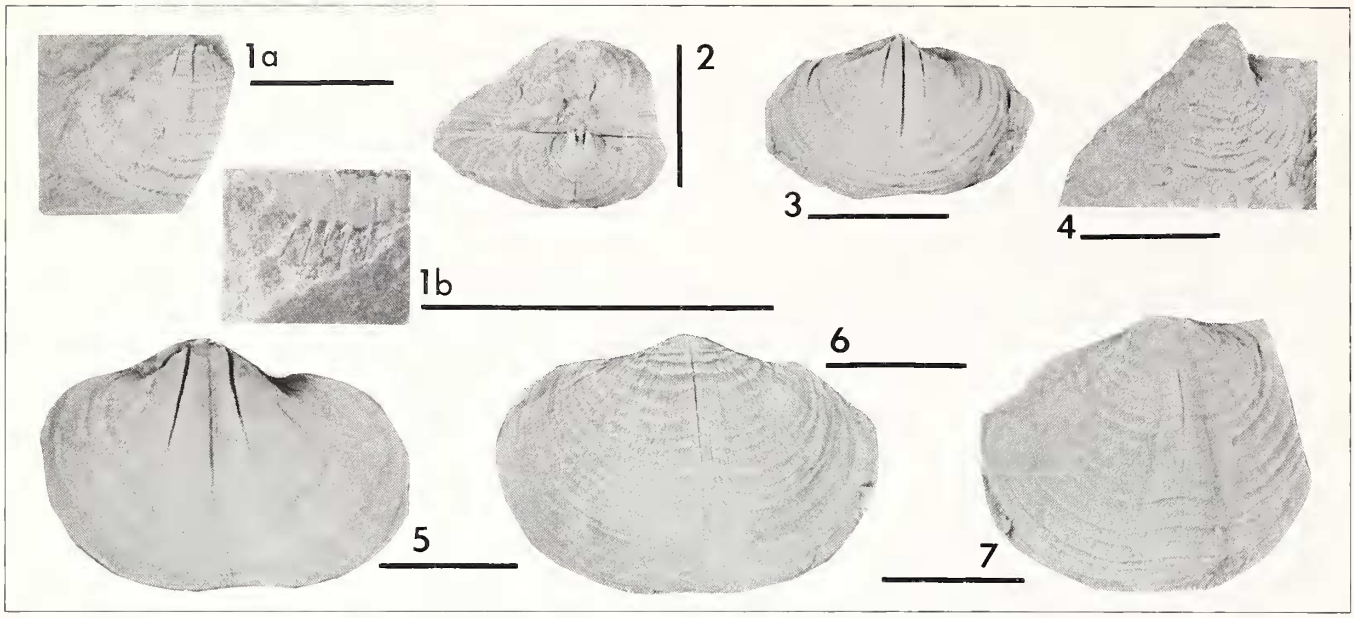


FIGURE 16. Toryniferella *sp.* 1a,b, *interior mold of pedicle valve, median septum and dental plates, with enlargement of double-barreled spines, Brandywine Falls, interval 69, CMNH 8499;* 2, *posterior view of pedicle valve beak and interarea, Brandywine Falls, interval 57, CMNH 8500;* 3, *interior mold of pedicle valve, Brandywine Falls, float, CMNH 8501;* 4, *interior mold of pedicle valve, Brecksville Reservation, interval 19, CMNH 8502;* 5, *interior mold of pedicle valve, Brandywine Falls, interval 69, CMNH 8503;* 6, *interior mold of brachial valve, Brandywine Falls, float, CMNH 8504;* 7, *interior mold of brachial valve, weak fold, Brandywine Falls, interval 43, CMNH 8405. Bar scale = 1 cm.*

CYRTOSPIRIFER SPICATUS Greiner, 1957
Figures 14.1-14.6

Description of material

Medium to large shell, extremely transverse; biconvex; hinge length increased by long, attenuated mucrons. Fold and sulcus fairly well-defined from beak to anterior margin. Interareas, costae, and other exterior features similar to *C. leboeufensis*. Pedicle valve interior distinguished by short dental plates, which extend one-third the length of the shell and diverge at a 45 degree angle. Spatulate muscle scar not enclosed by dental plates.

Remarks

Distinguishing characters for this species include faint growth lines as micro-ornament, the extremely transverse profile with exaggerated mucrons, the short, diverging dental plates, and the shape of the diductor muscle scar (Greiner, 1957). *Cyrtospirifer leboeufensis* and *C. spicatus* are for the most part indistinguishable in the field at either Brecksville or Brandywine Falls. Often, only fragments or partial specimens are recovered, and identifications to the species level are not possible. Therefore, in the brachiopod distribution data (Figures 2 and 3), the species are combined and charted together, at the generic level. *Cyrtospirifer* exhibits almost continuous occurrence in both sections studied. A few intervals in the upper third of the Brandywine Falls section lack species of this genus.

Genus *SPHENOSPIRA* Cooper, 1954
SPHENOSPIRA ALTA (Hall, 1867)
Figures 15.1-15.4

Description of material

Large size, triangular outline; valves unevenly biconvex; pedicle valve pyramidal, brachial valve shallow; greatest width at hinge; pedicle valve interarea finely striated with vertical and faint horizontal lines; posterior two-thirds of delthyrium covered by delthyrial plate, while stegidium covers anterior one-third, growing in increments as pedicle atrophies (Cooper, 1954). Lateral slopes, fold and sulcus are costate; costae originate at beak and terminate at anterior margin, increasing by bifurcation on lateral slopes. Pedicle and brachial valve interiors not observed.

Remarks

Prosser (1912) reported this species from Chippewa Creek at Brecksville Reservation. This species was also collected and described from Chippewa Creek by Cooper in 1954. Specimens in the National Museum of Natural History, Washington exhibit divergent dental plates in the interior of the pedicle valve, as well as radiating muscle scars between the plates. Museum specimens also show the cardinal process, teeth, and sockets. *Sphenospira alta* occurs, in low abundance, in the lower half of the section at Brecksville. Only two occurrences in the upper half were

recorded. Two specimens were found in situ in the lower half of the Brandywine Falls area, although several very large specimens were recovered from float in the creek. Occurrences are charted in Figures 2 and 3.

Superfamily RETICULARIACEA Waagen, 1883
Family ELYTHIDAE Fredericks, 1924
Genus *TORYNIFERELLA* Weyer, 1967
TORYNIFERELLA sp.
Figures 16.1-16.7

Description of material

Medium to large size (width greater than 25 mm in adults); transversely elliptical outline; biconvex; rounded margins; width greater than length; hinge length less than greatest width, which occurs at mid-valve; low interareas; open delthyrium. Valve exteriors ornamented by prominent concentric growth lines, each bearing numerous, regularly spaced, fine, double-barreled spines (Figure 16.1). Pedicle valve exterior with high umbonal region, and small, pointed, well-defined beak, which incurves over interarea; sulcus shallow or obsolete. Brachial valve exterior with low fold, set apart by a shallow groove on either side; umbo elevated, broad. Pedicle valve interior displays long, median septum, originating at umbo, extending approximately two-thirds of valve length. Median septum flanked by initially diverging dental plates, which extend one-half valve length, and then recurve slightly toward septum. Brachial valve interior with a thin, median ridge which begins approximately one-fourth the shell length from the posterior margin, and extends one-half of valve length. Two thin, short, parallel crura extend from hinge, terminating before median ridge begins. Crural plates form single plate across inner surface of crura, but do not attach to the valve floor.

Remarks

Toryniferella is easily distinguished from *Reticularia praematura* (Hall, 1866), which was reported in the Chagrin by Prosser (1912), by the presence of biramous, or double-barreled spines in the former genus, and uniramous spines in the latter genus. *Toryniferella* can be differentiated from *Torynifer* based on brachial valve morphology. *Torynifer* possesses a median septum in the brachial valve, which supports the cardinalia (Carter, 1988). The Chagrin specimens have no brachial median septum. *Toryniferella* is distinguished from *Kitakamithyris,* another elythid, by the presence in the former of crural plates which are not separated or divided, and which do not connect to the floor of the shell (Weyer, 1967).

Specimens of *Toryniferella* in the Chagrin Shale are generally incomplete. Original shell material is almost absent, and dorsal (brachial) beaks are often broken off. At this time, identification below the genus level is not possible.

Toryniferella is a relatively recently named genus (Weyer, 1967), and has not been reported widely in the literature. It is possible that reclassification of some specimens of *Torynifer* spp. and *Reticularia praematura* (Hall, 1866), the latter species having been reported from the Chagrin by Prosser (1912), may result in further additions of members to the genus. *Toryniferella* occurs in abundance in the lower half of the section at Brandywine Creek, and again in the upper third of the same section. In contrast, at Brecksville, this genus is sparse, occurring in four intervals in the lower half of the section, and in five intervals in the upper third (Figures 2 and 3).

Phylum MOLLUSCA Cuvier, 1797

Remarks

The Chagrin megafauna in the Cuyahoga River Valley is almost exclusively restricted to brachiopods. The only other faunal elements, with the exception of two unidentifable, pyritized, epibionts, are four taxa of bivalves. Their distribution is plotted in Figures 2 and 3.

Class BIVALVIA Linné, 1758 (Buonanni, 1681)
Subclass PTERIOMORPHIA Beurlen, 1944
Order PTERIOIDA Newell, 1965
Suborder PTERIINA Newell, 1965
Superfamily PTERIACEA Gray, 1847 (1820)
Family PTERINEIDAE Miller, 1877
Genus *LEPTODESMA* Hall, 1883
LEPTODESMA sp.
Figures 17.6, 17.8-17.10

Description of material

Small to medium size, biconvex. Hinge line straight from anterior extremity to posterior wing. Posterior wing terminates as a short spine. Surface ornament of fine to coarse, irregularly spaced concentric lines. Dentition, hinge, ligament and internal structures unknown. No shell material is preserved.

Remarks

Very small specimens of *Leptodesma* are often found concentrated on bedding planes in the Chagrin Shale. These could represent spatfalls, or juvenile specimens, which were buried before growth could proceed. This taxon is found at both locations, mainly in the lower halves of each section (Figures 2 and 3).

Superfamily PECTINACEA Rafinesque, 1815
Family PTERINOPECTINIDAE Newell, 1938
Genus *PTERINOPECTEN* Hall, 1883
PTERINOPECTEN? sp.
Figures 17.1-17.4

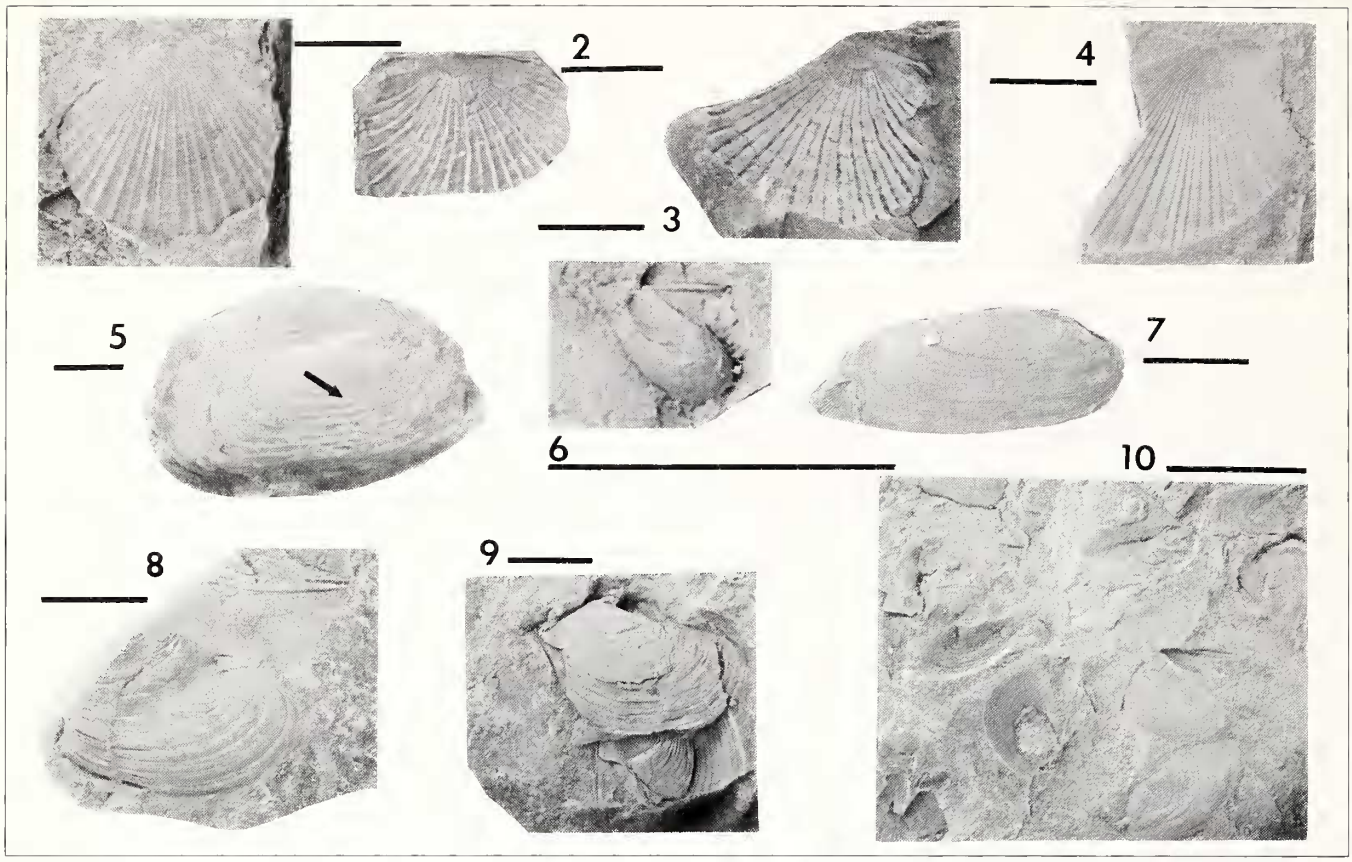


FIGURE 17. *Bivalvia.* 1-4, Pterinopecten? *sp.* 1, *interior mold, Brandywine Falls, float, CMNH 8506;* 2, *interior mold, Brandywine Falls, interval 58, CMNH 8507;* 3, *mold of exterior, with reticulate pattern formed by costa and growth lines, Brandywine Falls, interval 58, CMNH 8508;* 4, *exterior mold, subequal auricles, Brandywine Falls, interval 74, CMNH 8509;* 5, Sanguinolites *sp., interior mold of right valve, growth lines increase by intercalation and bifurcation (arrow), Brandywine Falls, float, CMNH 8510;* 7, Spathella? *sp., interior mold, right valve, Brandywine Falls, float, CMNH 8512;* 6, 8-10, Leptodesma *sp.* 6, *interior mold of left valve, with posterior spine, Brecksville Reservation, interval 25, CMNH 8511;* 8, *partial interior mold of left valve, Brandywine Falls, interval 62, CMNH 8513;* 9, *interior mold of disarticulated specimen, Brandywine Falls, interval 58, CMNH 8514;* 10, *molds of juvenile specimens, Brandywine Falls, float, CMNH 8515. Bar scale = 1 cm.*

Description of material

Small to medium size, generally flattened. Pectinid shell shape with subequal anterior and posterior ears. Hinge line straight, extending length of ears. Surface ornament of prominent radial ribs, crossed by concentric growth lines, resulting in a reticulated appearance. Shell material, dentition, hinge features, ligament and musculature unknown.

Remarks

Specimens were all collected from the Brandywine Falls location, either as float or in situ (Figure 3). No specimen is complete; information was obtained from partial molds.

Order MODIOMORPHOIDA Newell, 1969
Superfamily MODIOMORPHACEA S.A. Miller, 1877
Family MODIOMORPHIDAE S.A. Miller, 1877
Genus *SPATHELLA* Hall, 1885

SPATHELLA? sp.
Figure 17.7

Description of material

One medium size specimen was collected as float from a slab at Brandywine Falls. Right valve ovate, ornamented by evenly spaced, concentric growth lines. Beak prosogyrous. One shard of shell material remains on the specimen. Lunule and escutcheon, ligament, hinge, and musculature unknown.

Subclass ANOMALODESMATA Dall, 1889
Order PHOLADOMYOIDA Newell, 1965
Superfamily PHOLADOMYACEA Gray, 1847
Family GRAMMYSIIDAE S.A. Miller, 1877
Genus *SANGUINOLITES* M'Coy, 1844
SANGUINOLITES sp.
Figure 17.5

Description of material

One specimen was recovered from float at Brandywine Falls. Specimen large, elongate, with small umbones located in anterior third of shell. Beak prosogyrous. Ornament of very coarse comarginal rugae, which increase by bifurcation and intercalation (Figure 17.5).

Brachiopod distribution

The total number of genera and their distribution throughout both stratigraphic sections shows that brachiopods are fairly abundant in the lower one half to two thirds of each section (Figure 18). This is followed by a sharp drop in the number of genera to two at Brecksville and to zero at Brandywine. An especially silty interval is present at this position at Brandywine, and could account for the decrease in taxa, and for their inability to recolonize during the time of silt deposition. Silt was transported into the area by periodic storms (Weidner and Feldmann, 1983), and tended to obliterate brachiopod assemblages with rapid burial. There is also a possibility that turbidites were the dominant mechanism of rapid sedimentation. Lewis (1988, p. 24) evaluated different studies, and favors a storm mechanism and deposition of silts in the form of tempestites. After intervals of low abundance, abundance increases in the upper third of each section. Diversity is never as great as in the lower parts of both sections (Figure 18). Diversity declines near the contact with the Cleveland Shale, concommittant with a change to anoxic conditions.

Brachiopods such as *Cyrtospirifer* and *Centrorhynchus* are well distributed throughout both sections (Figures 2 and 3). This supports a conclusion that these two taxa were eurytopic, and represented pioneer species. *Cyrtospirifer* possessed a complex, spirolophous lophophore, which enhanced food and oxygen gathering capabilities. *Centrorhynchus* also had a spirolophous lophophore, but its resurgence after periodic disasters might possibly be due to an initial, epiplanktonic mode of existence, analogous to that suggested by Ager (1962; 1965). Some genera, such as *Sphenospira* and *Anlacella,* are abundant at one site and sparse at the other, while the faunal distributions of other genera, such as *Retichonetes, Acanthatia,* and *Schellwienella,* appear similar in both sections.

The composition and vertical distribution of the Chagrin fauna reflects colonization by opportunistic, pioneering species. Levinton (1970) distinguished between equilibrium species populations and opportunistic species populations. The former are resource-limited, or near the carrying capacity of the environment, which is stable and less likely to fluctuate over time. As a result, population levels tend to remain constant. Opportunistic species, on the other hand, are not resource limited, and increase rapidly in numbers. Under unstable environmental conditions, these species are considered physiological generalists; they tend to increase in numbers when space, temperature, salinity and other environmental factors become favorable.

Levinton (1970) offered several criteria for identifying opportunistic species. First, there is random orientation of specimens and lack of size sorting in individual beds, although dominant taxa tend to be grouped by size. In the Chagrin, this is especially true of the cyrtospiriferids and the rhynchonellids, which are numerically dominant and ubiquitous at the two sections.

Second, distribution over a limited area is characteristic, with adjacent, nonfossiliferous horizons. Within the study area, some layers are fossiliferous, while adjacent layers and areas may be fossil poor. The pattern of

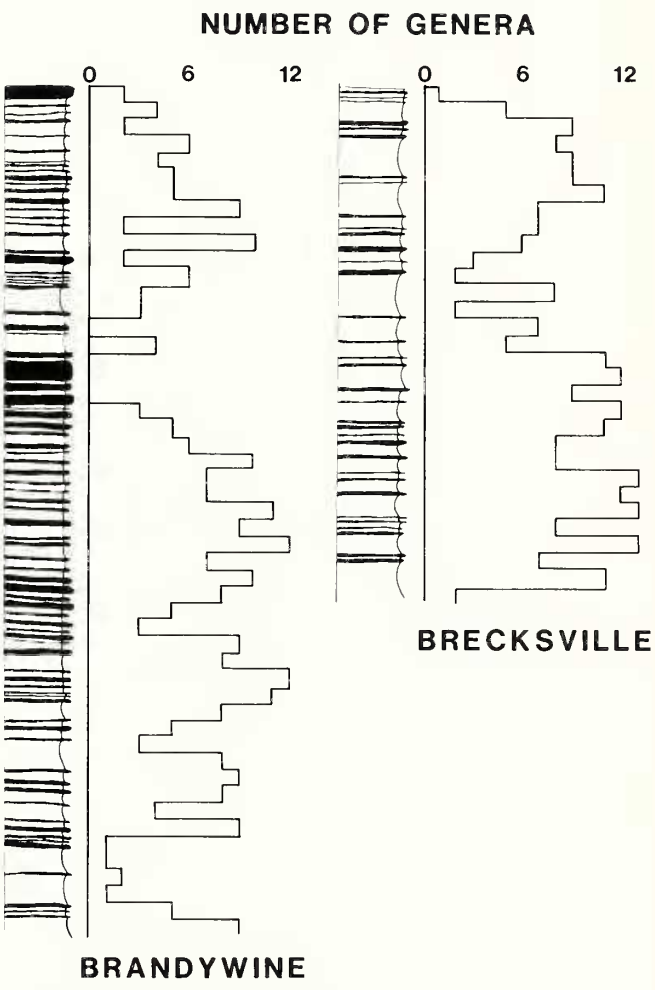


FIGURE 18. *Vertical distribution of taxa in the Cuyahoga Valley. The number of taxa within each 20 cm interval is plotted on a scale of zero to twelve. Both sections exhibit abundant taxa in the lower halves, a sharp drop in abundance in the upper one half to one third, and an increase in abundance in the upper portion. Taxa decrease again near the Chagrin-Cleveland boundary.*

distribution appears random. On a regional scale, very few Chagrin Shale outcrops in northeast Ohio contain the abundant brachiopod fauna found in the Cuyahoga River Valley. Adverse environmental conditions or lack of colonizing stock may account for this condition, although differential preservation must also be considered.

Third, stable faunal assemblages may be invaded by one dominant opportunistic species, leading to overwhelming domination of the assemblages (85-100%). This does not appear to be the case with the Chagrin fauna. Stable faunal assemblages never seemed to develop. After periods of rapid silt deposition, many of the species which were able to recolonize appear to be opportunists, with special morphologies for coping with stressed environments. New taxa did not appear in the section over time, possibly because the initial colonists had not sufficiently stabilized the substrate, and because the physical environment remained changeable. Most Chagrin brachiopods represent pioneer species, never rising much past an entry level for community succession. The same faunal elements continue to reestablish themselves after storm events. Very few taxa show distribution patterns which are anomalous in that they do not reflect pioneering characteristics throughout both sections (Figures 2 and 3). *Aulacella* is reported only once from the upper two thirds of the Brandywine Falls section, although it appears throughout the Brecksville section. *Sphenospira* is present in the lower half of Brecksville, and in two intervals in the upper half of that section, and in two intervals in the lower half of Brandywine Falls section. *Schellwienella* occurs in the lower halves of both sections, and once in the upper parts of both sections. The lingulids show the same general distribution pattern as *Schellwienella*. *Orbiculoidea* is found only at Brecksville and is not considered in this analysis. The other Chagrin brachiopods remain fairly constant in their distributions throughout the sections. Pioneer assemblages do not appear to have been replaced by more stable aggregations. Storm events were too frequent to allow for an orderly progression of faunal elements and community succession over time.

Alexander (1977) studied opportunistic brachiopods in Idaho and Utah. Many developed compressed body plans for suspension on a fluid substrate, which also served to increase oxygen diffusing mantle surfaces under oxygen deficient conditions. According to Alexander (1977), stressed communities are characterized by one dominant type of opportunist which can adapt to adverse conditions; by an absence of rugose and colonial corals, sponges, and bryozoans, which thrive in clear, oxygenated, less turbid waters; and by a variety of vacant niches, as evidenced by a lack of mobile faunal elements. The Chagrin environment was probably stressed, and faunal diversity is low, consisting of sessile organisms which can float in, or on, an unstable, muddy substrate, and which can feed and breathe under low oxygen, turbid conditions (Schwimmer, 1988). In this respect, the Chagrin brachiopods are opportunists, which exploited stressed habitats, and managed to establish and maintain pioneer communities.

The brachiopods collected in the Cuyahoga Valley Chagrin sequence provide the best evidence for a paleoenvironmental interpretation of the Chagrin Shale, due to their almost exclusive occurrence in the sediments at both locales. Their morphological adaptations and inferred life styles enhance our understanding of conditions at the time of deposition. Further, their distribution patterns at the two sites may aid in correlation of the two sections. It is anticipated that detailed collection at sites in the central and western portions of the Chagrin outcrop belt would yield similar brachiopod faunas and distributions.

Age of the Chagrin Shale

On the evidence of its conodont and brachiopod faunas, the Chagrin Shale is Late Devonian (Famennian) in age. Schopf and Schwieterling (1970) and Murphy (1973) used the presence of the alga *Foerstia,* obtained from locales in Ashtabula County, to correlate the Chagrin with other Upper Devonian units in northwestern Pennsylvania and southwestern New York. Murphy (1973) reported *Foerstia* near the base of the Ellicott Shale Member of the Chadakoin Formation in Pennsylvania and New York. This formation is included in the Conneaut Group of the upper Cassadagan Stage. Schopf (in Feldmann et al., 1978) commented that the *Foerstia* zone probably was within the Upper Cassadagan Stage. Feldmann et al. (1978) speculated that the Chagrin could extend into the Bradfordian Stage (Fammenian).

Brachiopods found in the Chagrin Shale support a Famennian age. Dutro (1981) reported that *Cyrtospirifer spicatus* Greiner and *Sphenospira alta* (Hall) occur in the Venango and Cattaraugus formations, assigned to the Famennian Conewangoan Stage of Cooper et al. (1942), equivalent to the Bradfordian Stage of Rickard (1975).

The most definitive age data for the Chagrin Formation come from a recent conodont analysis, reported by Zagger and Banks (1988), from the Skinner's Run pyrite bed, mentioned earlier. Anita Harris (U.S. Geological Survey, 1988, pers. comm.) identified specimens of *Polygnathus exerplexus* Sandberg and Zeigler, 1979 and *Bispathodus aculeatus* (Branson and Mehl, 1934) from the Zagger and Banks (1988) collection. These indicate correlation with the Middle *expansa* subzone (Sandberg and Zeigler, 1984) of late Famennian age. *Polygnathus exerplexus* is restricted to the Lower to Middle *expansa* Zone, and *Bispathodus aculeatus,* although with a greater stratigraphic range, first occurs in the Middle *expansa* subzone (Harris, 1988, pers. comm.).

Conclusions

Nineteen taxa of brachiopods and four taxa of bivalves are described here from the Upper Devonian Chagrin Shale of the Cuyahoga River Valley in northeast Ohio. The Chagrin sediments were deposited on a relatively shallow marine shelf, below normal wave base. Episodic storms are thought to have carried sediments westward from the prograding Catskill Delta complex, leading to the periodic burial of brachiopod assemblages. Brachiopods are generally preserved as molds, with occasional shell material. Some molds are coated with pyrite. Pyrite also occurs in sediments as nodules or burrow infillings. Lingulid brachiopods are preserved in phosphatic concretions. The infrequent fragmentation and abrasion of specimens suggests rapid burial rates. The composition and distribution patterns of brachiopod assemblages implies population by pioneering species, which were able to survive under adverse conditions. Stressed conditions precluded colonization by stenotopic faunal elements. Brachiopod distribution patterns at the two sites suggest a rough correspondence in assemblage composition. Conodont evidence provides an Upper Famennian age for the Chagrin, as does the occurrence of the brachiopod *Sphenospira alta*.

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